Appendix J1

Geologic Assessment

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ZARA ENVIRONMENTAL LLC
1707 West FM 1626
Manchaca, Texas 78652
www.zaraenvironmental.com

GEOLOGICAL ASSESSMENT FOR U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD, BEXAR COUNTY, TEXAS

Caption: Surveyor exiting Taco Truck Tunnel (feature 281-025) during excavation.

Prepared for
Jacobs Engineering Group
2505 Bee Cave Road
Suite 300
Austin, Texas 78746-5688

6 December 2010

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GEOLOGICAL ASSESSMENT FOR U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD, BEXAR COUNTY, TEXAS

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6 December 2010

In accordance with the Texas Board of Professional Geologists rules at 22 Texas Administrative Code, Part 39, Chapter 851, Subchapter C, §851.156, this report is signed and sealed on the title page to assure the user that the work has been performed by or directly supervised by the following professional geologist who takes full responsibility for this work.

The computer generated seal appearing on this document was authorized by Marcus O. Gary, Ph.D., P.G. 10386, on 6 December 2010.

STATE OF TEXAS
MARCUS O. GARY
GEOLOGY
10386
LICENSED
PROFESSIONAL GEOSCIENTIST

6 December 2010
Marcus O. Gary, Texas Professional Geologist No. 10386

Table of Contents

Geologic Assessment
For Regulated Activities
on The Edwards Aquifer Recharge/transition Zones
and Relating to 30 TAC §213.5(b)(3), Effective June 1, 1999

REGULATED ENTITY NAME: Alamo RMA Loop 1604 Environmental Impact Study (EIS).

TYPE OF PROJECT: _X_ WPAP __ AST __ SCS __ UST

LOCATION OF PROJECT: _X_ Recharge Zone _X_ Transition Zone _X_ Contributing Zone within theTransition Zone

PROJECT INFORMATION

1. _X_ Geologic or manmade features are described and evaluated using the attached **GEOLOGIC ASSESSMENT TABLE**.

2. Soil cover on the project site is summarized in the table below and uses the SCS Hydrologic Soil Groups* (*Urban Hydrology for Small Watersheds, Technical Release No. 55, Appendix A*, Soil Conservation Service, 1986). If there is more than one soil type on the project site, show each soil type on the site Geologic Map or a separate soils map.

Abrev	Name	Group*	Min Depth (cm)	Max Depth (cm)
Bre	Brackett gravelly clay loam, 12 to 20 percent slopes	A	15	51
Bte	Brackett Eckrant Association, 12 to 20 percent slopes	A	6	20
Ca	Anhalt clay, 0 to 1 percent slopes	D	51	102
Cb	Crawford and Bexar stony soils	C	51	102
Kr	Krum clay, 1 to 5 percent slopes	A	>203	N/A
Or	Orif soils, 0 to 1 percent slopes, frequently flooded	A	>203	N/A
Pt	Pits and Quarries, 1 to 90 percent slopes	N/A	N/A	N/A
TaB	Eckrant cobbly clay, 1 to 5 percent slopes	B	20	51
TaC	Eckrant cobbly clay, 5 to 15 percent slopes	B	20	51
TaD	Eckrant-Rock outcrop complex, 15 to 60 percent slopes	A	15	51
Tf	Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded	A	>203	N/A

* Soil Group Definitions (Abbreviated)
A. Soils having a high infiltration rate when thoroughly wetted.
B. Soils having a moderate infiltration rate when thoroughly wetted.
C. Soils having a slow infiltration rate when thoroughly wetted.
D. Soils having a very slow infiltration rate when thoroughly wetted.

3. _X_ A **STRATIGRAPHIC COLUMN** is attached at the end of this form that shows formations, members, and thicknesses. The outcropping unit should be at the top of the stratigraphic column.

4. _X_ A **NARRATIVE DESCRIPTION OF SITE SPECIFIC GEOLOGY** is attached at the end of this form. The description must include a discussion of the potential for fluid movement to the Edwards Aquifer, stratigraphy, structure, and karst characteristics of the site.

5. _X_ Appropriate **SITE GEOLOGIC MAP(S)** are attached:

The Site Geologic Map must be the same scale as the applicant's Site Plan. The minimum scale is 1":400'

Applicant's Site Plan Scale	1" = 3,654 '
Site Geologic Map Scale	1" = 400 '
Site Soils Map Scale (if more than 1 soil type)	1" = 400 '

6. Method of collecting positional data:

_X_ Global Positioning System (GPS) technology.
___ Other method(s).

7. _X_ The project site is shown and labeled on the Site Geologic Map.

8. _X_ Surface geologic units are shown and labeled on the Site Geologic Map.

9. _X_ Geologic or manmade features were discovered on the project site during the field investigation. They are shown and labeled on the Site Geologic Map and are described in the attached Geologic Assessment Table.
___ Geologic or manmade features were not discovered on the project site during the field investigation.

10. _X_ The Recharge Zone boundary is shown and labeled, if appropriate.

11. All known wells (test holes, water, oil, unplugged, capped and/or abandoned, etc.):

__ There are 10 (#) wells present on the project site and the locations are shown and labeled. (Check all of the following that apply.)
X The wells are not in use and have been properly abandoned.
_ The wells are not in use and will be properly abandoned.
X The wells are in use and comply with 16 TAC Chapter 76.
__ There are no wells or test holes of any kind known to exist on the project site.

ADMINISTRATIVE INFORMATION

12. ___ One (1) original and three (3) copies of the completed assessment has been provided.

Date(s) Geologic Assessment was performed: October 1, 2009 - November 25, 2010
Date(s)

To the best of my knowledge, the responses to this form accurately reflect all information requested concerning the proposed regulated activities and methods to protect the Edwards Aquifer. My signature certifies that I am qualified as a geologist as defined by 30 TAC Chapter 213.

Marcus O. Gary, Ph.D., P. G.
Print Name of Geologist

(512) 291-4555
Telephone

(866) 908-9137
Fax

Signature of Geologist

December 6, 2010
Date

Representing: Zara Environmental, LLC .
(Name of Company)

If you have questions on how to fill out this form or about the Edwards Aquifer protection program, please contact us at 210/490-3096 for projects located in the San Antonio Region or 512/339-2929 for projects located in the Austin Region.

Individuals are entitled to request and review their personal information that the agency gathers on its forms. They may also have any errors in their information corrected. To review such information, contact us at 512/239-3282.

TCEQ-0585 (Rev. 10-01-04)

GEOLOGIC ASSESSMENT TABLE						PROJECT NAME:									U.S. 281 EIS					
LOCATION			FEATURE CHARACTERISTICS												EVALUATION			PHYSICAL SETTING		
1A	1B *	1C*	2A	2B	3	4			5	5A	6	7	8A	8B	9	10		11		12
FEATURE ID	LATITUDE	LONGITUDE	FEATURE TYPE	POINTS	FORMATION	DIMENSIONS (FEET)			TREND (DEGREES)	DOM	DENSITY (NO/FT)	APERTURE (FEET)	INFILL	RELATIVE INFILTRATION RATE	TOTAL	SENSITIVITY		CATCHMENT AREA (ACRES)		TOPOGRAPHY
						X	Y	Z		10						<40	≥40	<1.6	≥1.6	
281-001	29.71045	-98.44968	MB	30	Kgru						1		N	5	35	X		X		Hillside
281-002	29.70747	-98.44963	O	5	Kgru	6.6	23	1			1		X	5	10	X		X		Cliff
281-003	29.70845	-98.44908	O	5	Kgru	23	6.6	1			1		X	5	10	X		X		Cliff
281-004	29.70145	-98.45075	CD	5	Kgru	2.3	1.6	0.8			1		O,F	10	15	X		X		Hillside
281-005	29.70197	-98.45067	CD	5	Kgru	4.9	3.8	1.6			1		O	10	15	X		X		Hilltop
281-006	29.70398	-98.45097	SF	20	Kgru	2.6	1.3	3.3	145	10	1	0.3	N	5	35	X		X		Cliff
281-007	29.70342	-98.45105	SC	20	Kgru	2.3	1.6	1.6			1	0.6	N	5	25	X		X		Cliff
281-008	29.69787	-98.45185	SC	20	Kgru	1.3	0.3	4.9			1	1.3	N	5	25	X		X		Cliff
281-009	29.70157	-98.45145	CD	5	Kgru	4.9	3.8	1			1		C	5	10	X		X		Hilltop
281-010	29.70450	-98.45208	O	5	Kgru	6.6	3.3				1		X	5	10	X		X		Cliff
281-011	29.69632	-98.45340	CD	5	Ked	8.2	4.9	3.3			1		C	5	10	X				Hillside
281-012	29.70550	-98.45142	SC	20	Kgru	0.7	0.7				2	0.7	N	0	20	X			X	Drainage
281-013	29.69255	-98.45307	SH	20	Kkd	2.5	3.3	2.3			1		O	15	35	X		X		Hilltop
281-014	29.69298	-98.45317	CD	5	Kkd	4.9	3.3	2.3			1		F	15	20	X		X		Hilltop
281-015	29.69202	-98.45372	SH	20	Kkd	5.2	2.6	0.8			1		F	10	30	X		X		Hilltop

* DATUM: WGS 84

2A	TYPE	2B POINTS
C	Cave	30
SC	Solution cavity	20
SF	Solution-enlarged fracture(s)	20
F	Fault	20
O	Other natural bedrock features	5
MB	Manmade feature in bedrock	30
SW	Swallow hole	30
SH	Sinkhole	20
CD	Non-karst closed depression	5
Z	Zone, clustered or aligned features	30

8A INFILLING	
N	None, exposed bedrock
C	Coarse - cobbles, breakdown, sand, gravel
O	Loose or soft mud or soil, organics, leaves, sticks, dark colors
F	Fines, compacted clay-rich sediment, soil profile, gray or red colors
V	Vegetation. Give details in narrative description
FS	Flowstone, cements, cave deposits
X	Other materials

12 TOPOGRAPHY

Cliff, Hilltop, Hillside, Drainage, Floodplain, Streambed

I have read, I understood, and I have followed the Texas Commission on Environmental Quality's Instructions to Geologists. The information presented here complies with that document and is a true representation of the conditions observed in the field. My signature certifies that I am qualified as a geologist as defined by 30 TAC Chapter 213.

Date December 6, 2010

Sheet 1 of 8

TCEQ-0585-Table (Rev. 10-01-04)

GEOLOGIC ASSESSMENT TABLE

PROJECT NAME: U.S. 281 EIS

LOCATION			FEATURE CHARACTERISTICS												EVALUATION			PHYSICAL SETTING		
1A	1B *	1C*	2A	2B	3	4			5	5A	6	7	8A	8B	9	10		11		12
FEATURE ID	LATITUDE	LONGITUDE	FEATURE TYPE	POINTS	FORMATION	DIMENSIONS (FEET)			TREND (DEGREES)	DOM	DENSITY (NO/FT)	APERTURE (FEET)	INFILL	RELATIVE INFILTRATION RATE	TOTAL	SENSITIVITY		CATCHMENT AREA (ACRES)		TOPOGRAPHY
						X	Y	Z		10						<40	≥40	<1.6	≥1.6	
281-016	29.66665	-98.44973	SF	20	Kkd	2.3	4.9	3.3			1	0.5	N	5	25	X		X		Cliff
281-017	29.67173	-98.45065	SC	20	Kkd	0.5	0.5	1.6			1		N	0	20	X		X		Cliff
281-018	29.67545	-98.45178	MB	30	Kkd						1		N	5	35	X		X		Cliff
281-019	29.68730	-98.45213	MB	30	Kkd						1		N	5	35	X		X		Hillside
281-020	29.68690	-98.45160	MB	30	Kkd	1.2	1	5.7			1		O	5	35	X		X		Hillside
281-021	29.68698	-98.45155	SH	20	Kkd	1.6	1.3	2.6			1		C, O	10	30	X				Hillside
281-022	29.68612	-98.45250	MB	30	Kkd						1		N	5	35	X		X		Hillside
281-023	29.68417	-98.45248	*MB*	30	Kkd						1		N	5	35	X		X		Hillside
281-024	29.68437	-98.45172	CD	5	Kkd	3.3	2.3	1			1		C, O	10	15	X		X		Hilltop
281-025	29.68432	-98.45082	C	30	Kkd	16.4	11.5	16.4	270		1	11.5	O,F,N	40	70		X		X	Hillside
281-026	29.66537	-98.44843	SH	20	Kkd	4.3	4.1	2			1		F	10	30	X		X		Hilltop
281-027	29.70997	-98.44735	MB	30	Kgru						1		N	5	35	X		X		Hillside
281-028	29.70848	-98.45891	MB	30	Kgru						1		N	5	35	X		X		Hillside
281-029	29.68908	-98.45418	SH	20	Kkd	3.3	3.3	1			1		O	40	60		X		X	Hillside
281-030	29.68907	-98.45407	SH	20	Kkd	4.1	4.1	2.5			1		C	10	30	X		X		Hilltop

* DATUM: WGS 84

2A	TYPE	2B POINTS
C	Cave	30
SC	Solution cavity	20
SF	Solution-enlarged fracture(s)	20
F	Fault	20
O	Other natural bedrock features	5
MB	Manmade feature in bedrock	30
SW	Swallow hole	30
SH	Sinkhole	20
CD	Non-karst closed depression	5
Z	Zone, clustered or aligned features	30

8A INFILLING	
N	None, exposed bedrock
C	Coarse - cobbles, breakdown, sand, gravel
O	Loose or soft mud or soil, organics, leaves, sticks, dark colors
F	Fines, compacted clay-rich sediment, soil profile, gray or red colors
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TCEQ-0585-Table (Rev. 10-01-04)

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						X	Y	Z		10						<40	>40	<1.6	>1.6	
281-031	29.68913	-98.45398	SH	20	Kkd	7.4	3.3	1.6			2		F, O	20	40		X	X		Hillside
281-032	29.68912	-98.45358	SH	20	Kkd	3.3	3.3	3			1		N	30	50		X		X	Hillside
281-033	29.68302	-98.45280	MB	30	Kkd						1		N	5	35	X		X		Hilltop
281-034	29.68353	-98.45195	MB	30	Kkd						1		N	5	35	X		X		Hillside
281-035	29.68052	-98.45488	CD	5	Kkd	19.7	4.9	0.8			3		F,O	5	10	X			X	Hilltop
281-036	29.68033	-98.45513	CD	5	Kkd	4.9	4.9	2.5			1		F,O	5	10	X			X	Hilltop
281-037	29.66333	-98.44880	C	30	Kkke	32.8	16.4	2.3	180	10	1		FS,N	30	70		X	X		Cliff
281-038	29.65918	-98.45175	SH	20	Kkke	7.5	3.3	1.3	130	10	1		O	20	50		X	X		Hilltop
281-039	29.65780	-98.45147	CD	5	Kkke	4.9	2.5	1.6			1		C	5	10	X		X		Hilltop
281-040	29.65716	-98.45121	CD	5	Kkke	4.6	4.6	2			1		O	5	10	X		X		Hillside
281-041	29.65735	-98.45180	SF	20	Kkke	4.1	2.5	2	120	10	1		O	20	50		X	X		Hilltop
281-042	29.65800	-98.45153	CD	5	Kkke	3.3	10.7	1			2		O	5	10	X		X		Hillside
281-043	29.64952	-98.45155	CD	30	Kkke	6.6	8.2	3.3			1		C,O	20	50		X	X		Hillside
281-044	29.65012	-98.45112	SH	20	Kkd	8.2	4.1	5.9			1		F,C	15	35	X			X	Hillside
281-045	29.65198	-98.45023	C	30	Kkd	23	13.1	2.3			1	2	N	25	55		X		X	Drainage

* DATUM: WGS 84

2A	TYPE	2B POINTS
C	Cave	30
SC	Solution cavity	20
SF	Solution-enlarged fracture(s)	20
F	Fault	20
O	Other natural bedrock features	5
MB	Manmade feature in bedrock	30
SW	Swallow hole	30
SH	Sinkhole	20
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8A INFILLING	
N	None, exposed bedrock
C	Coarse - cobbles, breakdown, sand, gravel
O	Loose or soft mud or soil, organics, leaves, sticks, dark colors
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TCEQ-0585-Table (Rev. 10-01-04)

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FEATURE ID	LATITUDE	LONGITUDE	FEATURE TYPE	POINTS	FORMATION	DIMENSIONS (FEET)			TREND (DEGREES)	DOM	DENSITY (NO/FT)	APERTURE (FEET)	INFILL	RELATIVE INFILTRATION RATE	TOTAL	SENSITIVITY		CATCHMENT AREA (ACRES)		TOPOGRAPHY
						X	Y	Z		10						<40	>40	<1.6	>1.6	
281-046	29.65645	-98.45100	CD	5	Kkd	3.3	3.3	1.6			1		F,O	10	15	X		X		Hilltop
281-047	29.65500	-98.45080	SH	20	Kkd	4.9	3.3	1.3			1		F,O	15	35	X			X	Hillside
281-048	29.64750	-98.45260	SH,Z	30	Kkke	9.8	3.3	6.6	85		1	3.3	F,O	20	50		X	X		Hilltop
281-049	29.69062	-98.45445	MB	30	Kkd						1		N	5	35	X		X		Hilltop
281-050	29.68797	-98.45167	MB	30	Kkd						1		N	5	35	X		X		Hillside
281-051	29.66725	-98.44897	SF, Z	20	Kkke	8.2	0.7	1	90	10	1	0.7	F,O	30	60		X	X		Hilltop
281-052	29.66087	-98.45171	CD	5	Kkd	32.8	32.8	4.9			1		O	5	10	X		X		Hillside
281-053	29.66089	-98.45192	CD	5	Kkd	9.8	2	3.3			1		O	5	10	X		X		Hillside
281-054	29.63959	-98.45328	SC	20	Kkd	26.2	1	2			1		FS	15	35	X		X		Cliff
281-055	29.63985	-98.45314	C/SC	30	Kkd	6.6	5.6	3.3	90	10	1		FS	30	70		X	X		Cliff
281-056	29.61860	-98.46550	CD	5	Kprd	3.3	3.3	2.5			1		O,F	5	10	X		X		Floodplain
281-057	29.62010	-98.46435	SH	20	Kplc	4.9	4.9	1.3			1		O	30	50		X	X		Hillside
281-058	29.62078	-98.46328	SH	20	Kplc	11.5	11.5	2.3			1		O, V	20	40		X			Hillside
281-059	29.63440	-98.45593	CD	5	Kkd	16.4	9.8	1.6			1		O,F, V	10	15	X		X		Hilltop
281-060	29.62458	-98.46348	SC	20	Kplc	7.4	1	1.6			1	0.7	F,C	10	30	X		X		Cliff

* DATUM: WGS 84

2A	TYPE	2B POINTS
C	Cave	30
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STATE OF TEXAS
MARCUS O. GARY
GEOLOGY
10386
LICENSED
PROFESSIONAL GEOSCIENTIST

Date December 6, 2010

Sheet 4 of 8

TCEQ-0585-Table (Rev. 10-01-04)

GEOLOGIC ASSESSMENT TABLE			PROJECT NAME:											U.S. 281 EIS						
LOCATION			FEATURE CHARACTERISTICS												EVALUATION			PHYSICAL SETTING		
1A	1B *	1C*	2A	2B	3	4			5	5A	6	7	8A	8B	9	10		11		12
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						X	Y	Z		10						<40	≥40	<1.6	≥1.6	
281-061	29.62918	-98.46097	SF	20	Kkd	1.3	2.9	4.1	90	10	1	1.3	O, C	10	40		X	X		Cliff
281-062	29.62940	-98.46088	C	30	Kkd	17.7	4.9	11	90	10	1		N,F,C	25	65		X	X		Cliff
281-063	29.62947	-98.46080	C	30	Kkd	23	3.3	4.6	90	10	1		N,FS,C	40	80		X	X		Cliff
281-064	29.62988	-98.46060	CD	5	Kkd	6.5	6.5	1			1		O,F	10	15	X		X		Cliff
281-065	29.63537	-98.45763	SF	20	Kkd	1.6	3.3	1.6	80	10	1		N	25	55		X		X	Cliff
281-066	29.62937	-98.46093	SC	20	Kkd	1.6	0.8	4.1	90	10	1	1.6	C,F	5	35	X		X		Cliff
281-067	29.66098	-98.45115	SH	20	Kkd	3.3	3.3	1			1		C,O	15	35	X			X	Hilltop
281-068	29.66097	-98.45088	MB	30	Kkd						1		N	5	35	X		X		Hillside
281-069	29.66037	-98.44993	SC	20	Kkke	4.9	1.6	4.9			1	1.6	C	10	30	X		X		Cliff
281-070	29.66030	-98.44992	C	30	Kkke	29.5	6.6	3.3	60		1	6.6	FS, C	20	50		X	X		Cliff
281-071	29.66025	-98.44993	SC	20	Kkke	9.8	6.6	4.3	100		1	6.6	FS,N	20	40		X	X		Cliff
281-072	29.66013	-98.44992	SC	20	Kkke	8.2	1.3	4.9			1		C	20	40		X	X		Cliff
281-073	29.66008	-98.44994	C	30	Kkke	32.8	3.3	3.9	80	10	1	3.2	FS,N	20	60		X	X		Cliff
281-074	29.65952	-98.44995	SC	20	Kkke	3.3	1	3.3			1		F	10	30	X		X		Cliff
281-075	29.65880	-98.44995	SC	20	Kkke	4.9	4.9	6.6			1		O, C	20	40		X			Cliff

* DATUM: WGS 84

2A	TYPE	2B POINTS
C	Cave	30
SC	Solution cavity	20
SF	Solution-enlarged fracture(s)	20
F	Fault	20
O	Other natural bedrock features	5
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SH	Sinkhole	20
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Z	Zone, clustered or aligned features	30

8A INFILLING	
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V	Vegetation. Give details in narrative description
FS	Flowstone, cements, cave deposits
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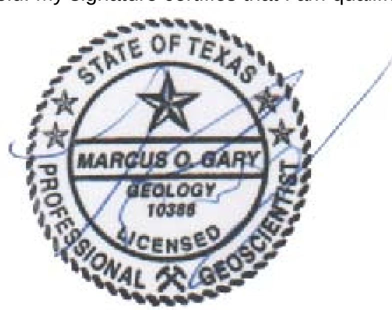

Date December 6, 2010
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GEOLOGIC ASSESSMENT TABLE

PROJECT NAME: U.S. 281 EIS

LOCATION			FEATURE CHARACTERISTICS												EVALUATION			PHYSICAL SETTING		
1A	1B *	1C*	2A	2B	3	4			5	5A	6	7	8A	8B	9	10		11		12
FEATURE ID	LATITUDE	LONGITUDE	FEATURE TYPE	POINTS	FORMATION	DIMENSIONS (FEET)			TREND (DEGREES)	DOM	DENSITY (NO/FT)	APERTURE (FEET)	INFILL	RELATIVE INFILTRATION RATE	TOTAL	SENSITIVITY		CATCHMENT AREA (ACRES)		TOPOGRAPHY
						X	Y	Z		10						<40	>40	<1.6	>1.6	
281-076	29.64158	-98.45372	SC	20	Kkd	1.6	1	3.3	75	10	1		N	10	40		X	X		Cliff
281-077	29.64252	-98.45323	SC	20	Kkd	0.8	0.8	1.3	150		1	0.8	C, F	10	30	X		X		Cliff
281-078	29.64320	-98.45283	SC	20	Kkd	4.9	3.3	1.6	75	10	1	0.7	C,F	15	45		X	X		Cliff
281-079	29.67902	-98.45147	O	5	Kkd	1.3	1	1.6			1		O	5	10	X		X		Hillside
281-080	29.61360	-98.46777	C	30	Kplc	62.3	6.6	17.4	45		1	6.6	FS, C, F	40	70		X	X		Hillside
281-081	29.63450	-98.45812	SC	20	Kkd	4.9	1	4.1	45		1		FS, C	20	40		X	X		Cliff
281-082	29.64395	-98.45303	SC	20	Kkke	9.8	1.6	3.3			1		F,C	15	35	X	X	X		Cliff
281-083	29.65985	-98.45048	C	30	Kkke	42.7	16.4	3.3			1	16.4	FS,N	35	65		X	X		Cliff
281-084	29.65988	-98.45048	SC	20	Kkke	9.8	6.6	4.1			1		C, F	10	30	X	X	X		Cliff
281-085	29.65982	-98.45047	SC	20	Kkke	13.1	8.2	9.8	90	10	1	8.2	C, FS, F	30	60		X	X		Cliff
281-086	29.65958	-98.45047	SC	20	Kkke	1.5	6.6	3.3			1	6.6	C	20	40		X	X		Cliff
281-087	29.65923	-98.45047	SC	20	Kkke	4.9	9.8	4.9			1	9.8	N, FS	10	30	X		X		Cliff
281-088	29.65939	-98.44987	C	30	Kkke	124.7	16.4	4.9	90		1	16.4		40	70		X	X		Cliff
281-089	29.65930	-98.44989	C	30	Kkke	124.7	16.4	4.9	90		1	16.4		40	70		X	X		Cliff
281-090	29.63733	-98.45660	C	30	Kkd	6.6	8.2	9.8			1	8.2	FS	40	70		X	X		Cliff

* DATUM: WGS 84

2A	TYPE	2B POINTS
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8A INFILLING	
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GEOLOGIC ASSESSMENT TABLE — PROJECT NAME: U.S. 281 EIS

LOCATION			FEATURE CHARACTERISTICS												EVALUATION			PHYSICAL SETTING		
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						X	Y	Z		10						<40	>40	<1.6	>1.6	
281-091	29.65921	-98.44988	C	30	Kkke	124.7	16.4	4.9	90		1	16.4		40	70		X	X		Cliff
281-092	29.70371	-98.45103	Fault	20	Kgru	0.5	0.5	10	53	10	1	0.01	N	10	40		X	X		Cliff
281-093	29.70379	-98.45103	Fault	20	Kgru	0.1	0.1	8	55	10	1	0.01	N	10	40		X	X		Cliff
281-094	29.64755	-98.45248	CD	5	Kkke	13.1	4.9	1			1		F,O,C	15	20	X		X		Hilltop
281-095	29.68201	-98.45353	SC	20	Kkd	6.6	3.3	3.3	133		1		FS	15	35	X			X	Cliff
281-096	29.68207	-98.45353	SC	20	Kkd	3.9	3.3	4.9			1		C	15	35	X		X		Cliff
281-097	29.64975	-98.45132	CD	5	Kkke	32.8	82	13.1			1		C, O	20	25	X		X		Hillside
281-098	29.70558	-98.45110	SC	20	Kgru	1	2.5	5.2	150		1	2.5	C	20	40		X		X	Floodplain
281-099	29.70027	-98.45099	CD	20	Kgru	3.3	2.6	0.7			1		O	10	30	X			X	Hillside
281-100	29.69547	-98.45128	MB	30	Kgru						1		N	5	35	X		X		Hillside
281-101	29.69415	-98.45251	MB	30	Ked						1		N	5	35	X		X		Hillside
281-102	29.68692	-98.45341	SC	20	Kkd	1	1	1			1	1	C	10	30	X		X		Cliff
281-103	29.65625	-98.45127	SC	20	Kkd	0.7	0.8	1.5			1	0.8	O	15	35	X		X		Hillside
281-104	29.62009	-98.46519	SC	20	Kprd	4.3	1.3	2.3			2	1.3	C	10	30	X		X		Cliff
281-105	29.63020	-98.46045	SC	20	Kkd	2.3	9.8	3.3			1	9.8	N	10	30	X		X		Cliff

* DATUM: WGS 84

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						X	Y	Z		10						<40	>40	<1.6	>1.6	
281-106	29.63550	-98.45687	SFZ	30	Kkd	15	20		106		6	0.3	C	15	45		X	X		Streambed
281-107	29.63971	-98.45355	SC	20	Kkd	4.3	4.9	0.8			1	4.9	C	15	35	X				Hillside
281-108	29.65444	-98.44859	CD	5	Kkd	2.6	2	1			1	2	O	5	10	X		X		Hillside
281-109	29.64756	-98.45228	SC	20	Kkke	0.3	0.6	0.7			2	0.6	O	15	35	X		X		Hillside
281-110	29.69489	-98.45223	F	20	Kgru				70	10				10	40					map
281-111	29.69353	-98.45235	F	20	Kkbn				55	10				10	40					map
281-112	29.68496	-98.45342	F	20	Kkd				57	10				10	40					map
281-113	29.66890	-98.45033	F	20	Kkd				59	10				10	40					map
281-114	29.65028	-98.45027	F	20	Kkke/KKd				64	10				10	40					map
281-115	29.64439	-98.45247	F	20	Kkke/KKd				60	10				10	40					map
281-116	29.62667	-98.46180	F	20	Kplc/Kkd				74	10				10	40					map

* DATUM: WGS 84

2A	TYPE	2B POINTS
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Sheet 8 of 8
TCEQ-0585-Table (Rev. 10-01-04)

Introduction

This geologic assessment (GA) has been prepared as a component of the environmental impact statement (EIS) material for proposed improvements to a large segment of U.S. Highway 281 in northern Bexar County, Texas. This GA was completed by performing a comprehensive review of previous GAs and other karst-related documents in the area, and conducting detailed walking field surveys of the existing right-of-way (ROW) and accessible properties immediately adjacent to the ROW for karst features. The study area for the GA includes a long segment of U.S. 281 that crosses the environmentally sensitive Edwards Aquifer Recharge Zone (EARZ) and portions of the Contributing Zone (EACZ) for which surface water drains to the Recharge Zone (Figure 1). A total of 116 features were documented and evaluated during the surveys, including natural and manmade features.

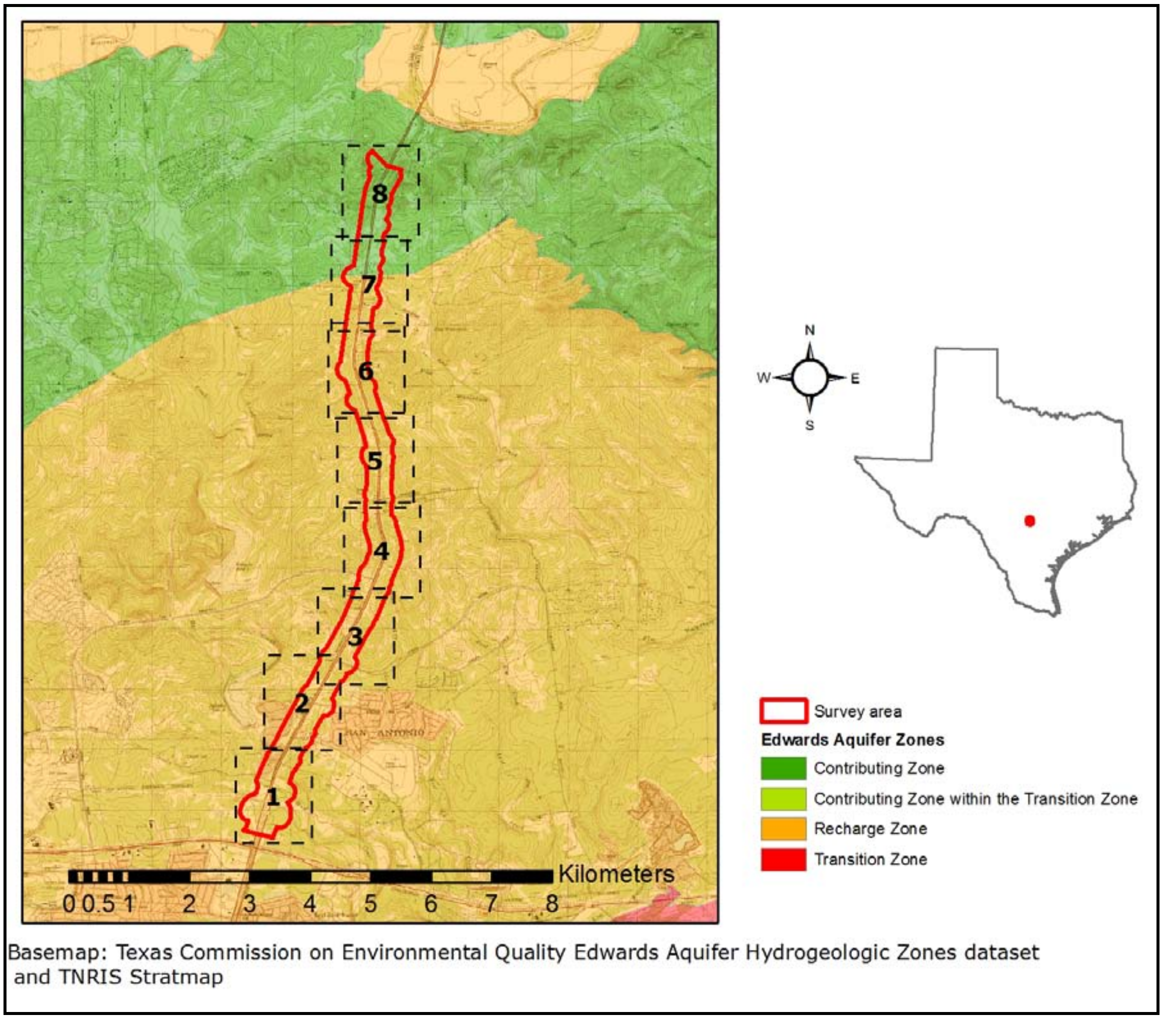

Figure 1. Location map of the U.S. 281 Geologic Assessment study area in northern Bexar County, Texas showing the individual map plates in Appendices C and D.

All features are documented in the preceding pages in the eitht GA tables, and each value has been evaluated for aquifer sensitivity. As much of the study area has been extensively altered by previous development and associated anthropogenic activity, many sensitive karst features may be obscured from direct observation. For this reason, other GAs were reviewed and features plotted on geological maps for this GA, but may not be included in the preceding GA table. A further discussion of additional features follows in the results section.

Methods

Karst survey methods followed protocols outlined in Texas Commission for Environmental Quality (TCEQ) Instructions to Geologists for Geologic Assessments (TCEQ, 2004) and U. S. Fish and Wildlife Service (USFWS) Section 10(a)(1)(A) Scientific Permit Requirements for Conducting Presence/Absence Surveys for endangered karst invertebrate species (USFWS, 2006).

A walking ground survey was completed in the study area and reconnaissance excavations were conducted at potential karst invertebrate habitat sites. As defined by Veni and Reddell (2002), Barrett (1999) and TCEQ (2004). Positions of all features were documented using a Trimble Juno Global Positioning System (GPS) and checked with field maps based on digital ortho-imagery. All features identified were inspected by a licensed professional geologist and evaluated for potential impact to Edwards Aquifer recharge. Field work for the karst survey was conducted between December 3, 2009 and October 5, 2010. Field work was supervised by Texas licensed professional geologist Marcus Gary. Additional individuals involved with field work for this GA are listed in the personnel section of this report.

A review of available literature on the area included analysis of past geologic assessments from the TCEQ files, files included in the administrative record for the U. S. 281 EIS, and the TSS cave database. A description of the current status of documented features within the U. S. 281 EIS project area is included in Appendix F of this report, and original feature names are shown on geology and soils maps. The existence of all of these features was field verified wherever possible in the ROW or within the 500-foot buffer of the ROW. If features remained observable (not covered by previous anthropogenic activity), they are included as a feature in this GA. All wells in the Texas Water Development Board (TWDB) database in the local area have also been reviewed and plotted on GA maps.

Background

Soils

Soil descriptions were compiled from the Web Soil Survey of the U. S. Department of Agriculture (USDA) (USDA, 2010), and site observations. Eleven different soil types are identified and described from the USDA dataset within the project area. These eleven soils are listed above (page 3) and details of all the soil types are presented in Appendix A. The spatial distribution is shown in Appendix C (Soils Maps).

Bedrock Geology

The U. S. 281 corridor is located in the southeastern portion of the Edwards Plateau Physiographic Province of central Texas, along the Balcones Fault Zone (BFZ) and within the Hill Country. The BFZ also forms the Balcones Escarpment, which is a highly eroded region bordering the Edwards Plateau on its southern and eastern boundaries. The region is typified by higher elevations to the north and west, generally sloping in a southeastern direction. Canyons and drainage basins were formed by surface flow of the San Antonio River Basin.

The geologic formations occurring within and surrounding the project area are comprised mostly of Cretaceous age-rocks with some overlaying Quaternary alluvium along surface drainages (Figure 2). The soils that have formed on top of these limestones are relatively thin and offer very minimal filtering capability. The limestone bedrock developed from the accumulation of thick sequences of marine sediments deposited in a lagoon environment on the San Marcos Platform protected by a barrier reef during the Cretaceous about 100 million years ago. In central Texas, the Cretaceous strata slightly dip to the southeast at about 10 to 15 feet per mile toward the Gulf of Mexico.

Major tectonic uplifting of the Edwards Plateau occurred along the BFZ during Miocene times about 15 million years ago, which resulted in accelerated erosion of the hill-country topography seen today. The boundary between the Edwards Plateau and Gulf Coastal Plain occurs along the trace of the BFZ. The BFZ is comprised mostly of northeast-southwest normal faults with displacement toward the southeast. The accumulative displacements for some of these fault sets can be greater than 1,000 feet. The Miocene faulting permitted meteoric water to percolate into the limestone allowing for extensive karstic diagenesis that resulted in interconnected, sometimes cavernous porosity of the prolific Edwards Aquifer.

Stratigraphy

The U.S. 281 corridor lies on rock comprised of limestones, clays, marls, sand, and alluvial deposits. Outcrops of more recent sediments of Quaternary alluvium and the Leona Formation are located along some drainages and low-lying areas, This sediment is a result of rocks eroded off the Balcones Escarpment and Edwards Plateau and re-deposited downstream. Much of the rest of the strata that is at the surface and subsurface in this area consists of Cretaceous age rocks. From youngest to oldest, they consist of the Edwards Limestone, and the Glen Rose Limestone.

The Person and Kainer Formations comprise the Edwards Group (Rose, 1972). The Person Formation is about 185 feet thick in northern Bexar County. The composition of the Person Formation ranges from crystalline limestone to grainstone to mudstone and is comprised of three informal hydrogeologic units: the cyclic and marine members, undivided; the leached and collapsed members, undivided; and the regional dense member.

The cyclic and marine members (Unit II) are composed of mudstone to fossiliferous packstone and are approximately 85 feet thick but can be somewhat variable in thickness because of the erosional unconformity between the Person and Georgetown Formations. The cyclic member is an alternating tidal flat deposit with small collapsed breccias, and the marine member is a cross-bedded biosparite to biomicrite with chert nodules.

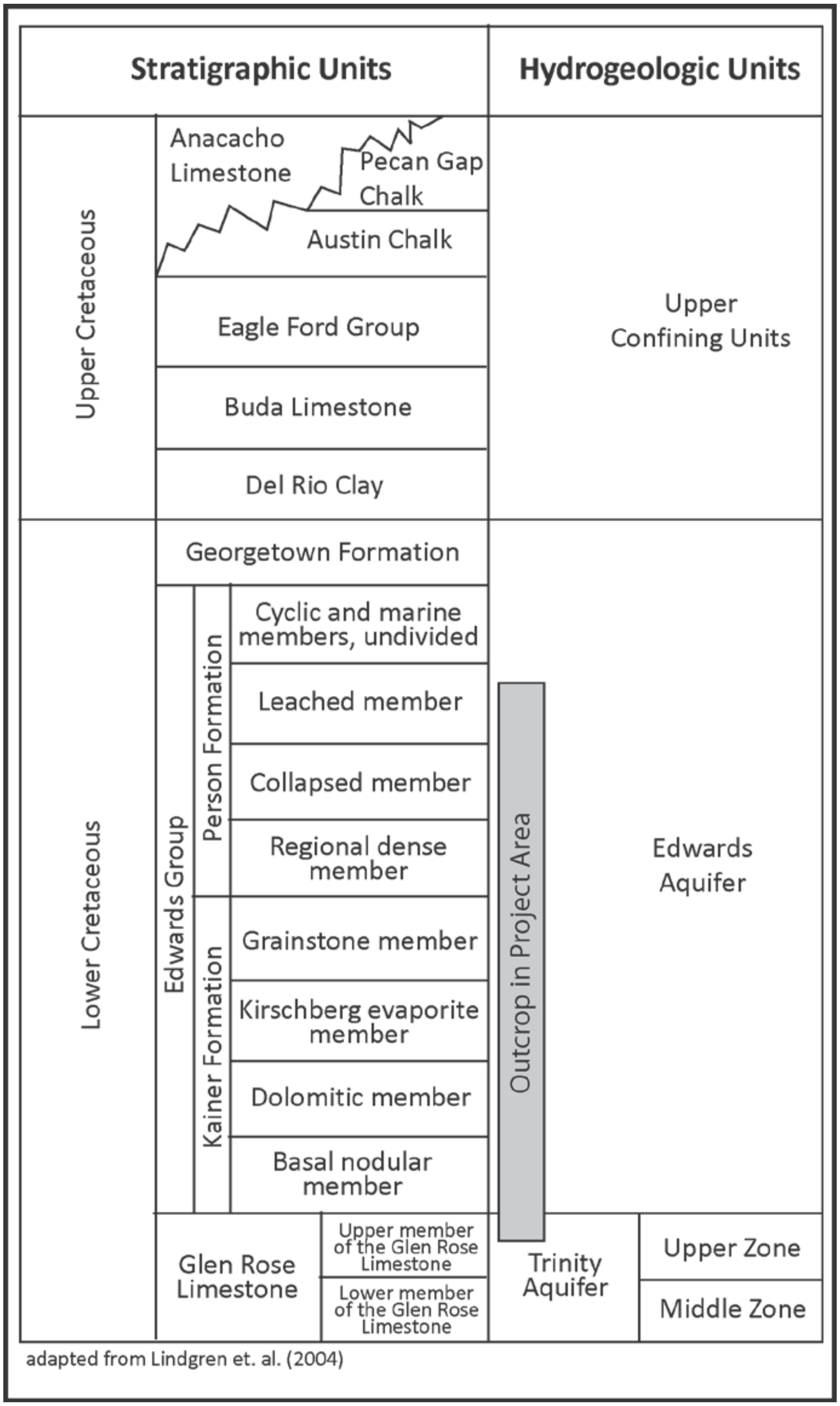

Figure 2. Stratigraphic column of rocks found in and surrounding the U.S 281 corridor. The primary rocks which crop out in the project area that falls within TCEQ Edwards Rules jurisdiction is shown by the gray shaded area.

The geological formations that comprise the Edwards Aquifer are from top to bottom the Georgetown, Person and Kainer. Maclay and Small (1976) divided the aquifer into eight hydrogeologic units (Units I through VIII), which are based on aquifer and

The leached and collapsed members (Unit III) are a sequence of interbedded mudstone and grainstone intervals that form one of the more porous and permeable subdivisions of the Edwards Aquifer. The leached member is a dense, bioturbated micrite and the collapsed member is composed of several one- to five-feet thick zones of collapsed stromatilitic limestone (Rose, 1972). Average thickness of the collapsed and leached members is approximately 80 feet in northern Bexar County and is characterized by two highly churned, iron stained beds separated by a more massive light colored limestone. Horizontal caverns with relatively large rooms develop in this unit.

The bottom unit of the Person Formation is the regional dense member (RDM) (Unit IV), which throughout the region has a relatively consistent thickness of 20 feet. The RDM is composed of a dense argillaceous mudstone and is easily identified in the outcrop and on a variety of geophysical logs. Most of the fractures that penetrate the RDM do not appear to be solution enlarged. Caves that breach the RDM are not enlarged but are usually vertical shafts with horizontal caverns developed above or below the RDM.

The RDM can function as a confining unit between the upper and lower portions of the Edwards Aquifer between the Kainer and the Person Formation. However, caves, faults, and fractures may greatly reduce the vertical confining ability of the RDM. The RDM is probably not an effective barrier to lateral flow at faults because of the relatively thin 20-foot section. The flow of water tends to circumvent the RDM because of the impermeable nature of this unit.

The Kainer Formation has an approximate total thickness of 285 feet. The lithology of the Kainer Formation ranges from mudstone to *miliolid* grainstone to crystalline limestone. The Kainer is subdivided into four informal members that include the grainstone, Kirschberg evaporate, dolomitic and basal nodular members.

The grainstone member (Unit V) is the uppermost unit of the Kainer Formation and is approximately 55-feet thick. Unit V is composed of thick sequences of dense, tightly-cemented, miliolid grainstone. Primary matrix porosity, as measured on geophysical logs, is some of the lowest in the Edwards Aquifer. Secondary fracture porosity accounts form the bulk of effective porosity in this aquifer unit.

The Kirschberg evaporite member (Unit VI) underlies the grainstone member and is about 60 feet in thickness. This hydrogeologic unit consists of crystalline limestone interbedded with mudstone containing chert lenses. Collapse features are common. The porosity has been described as boxwork (Maclay and Small, 1976) because of the configuration of the voids and the secondary neospar and travertine deposits. The boxwork porosity does not seem to be prevalent throughout the entire thickness or extent of subdivision VI, but occurs sporadically within more massive limestone. Dissolution of evaporite minerals, such as gypsum and anhydrite, and the existence of contorted beds in the Kirschberg evaporite results in extensive secondary porosity, which creates one of the most permeable subdivisions in the Edwards Aquifer.

The dolomitic member (Unit VII) is a dense, crystalline limestone with interbedded grainstone and burrowed mudstone with some chert beds. The dolomitic member has a total thickness of about 110 feet and is characterized by massive thick beds. Effective porosity and probable pathways of water in this unit are restricted to solution enlarged bedding planes, joints, fractures and faults.

The basal nodular member (Unit VIII) is the lowermost unit of the Edwards Group and is about 50 to 60 feet of tan, marly, nodular limestone. In the subsurface, the basal nodular member has negligible porosity and permeability (Maclay and Small, 1984), and can function as part of the lower confining unit. However, in outcrop the basal nodular member often displays extensive karstification, which has generated secondary porosity in the form of large lateral caves.

The upper Glen Rose Limestone (upper Trinity) acts as the lower confining unit for the Edwards Aquifer. The interbedded clays in the upper Glen Rose are restrictive to vertical flow and act to confine water in the Edwards Aquifer. A more detailed discussion of the Trinity is given below.

The Trinity Aquifer is an aquifer system that is composed of individual smaller layered aquifers within the geologic formations that comprise the Cretaceous-age Trinity Group. Trinity Group deposits include sands, limestones, shales and clays that were deposited before the Edwards limestone and, where present, are found beneath the Edwards Aquifer. The Trinity Group is divided into the following formations, in order from the shallowest to deepest: Glen Rose and Travis Peak (also known as the Pearsall Formation in Stricklin et al., 1971). The Travis Peak Formation of the lower Cretaceous is subdivided into the following members in order from shallowest to deepest: Bexar Shale or Hensell Sand, Cow Creek Limestone, Hammett Shale, Sligo Limestone and Hosston Sand.

The Glen Rose Formation has been divided informally into two members, lower and upper. The upper member of the Glen Rose Formation is an alternating sequence of limestone and marly clay that, when weathered, creates the distinctive "stair-step" topography found throughout much of the Hill Country. The upper Glen Rose member weathers to a yellowish-brown and develops characteristic yellowish tan soils, in contrast with the Edwards outcrop soils of grayish black.

In northern Bexar County, the upper Glen Rose member is up to 500 feet thick and contains two prominent evaporite beds. Each bed ranges from 20 to 30 feet thick and is composed of yellow marl, dolomite, and white chalky limestone (Reeves, 1967). Irregular bedding may be present from the removal of anhydrite and gypsum by solutioning. Springs and seeps are often located along outcrops of the evaporite beds. The upper Glen Rose member yields small quantities of water to wells and the water is often of poor quality (Reeves, 1967). Because of the presence of gypsum and anhydrite found near the middle and bottom of the upper Glen Rose, the evaporite beds produce water with high sulfate and total dissolved solids content. Permeability and water quality can be better in areas with solution enlarged fractures or faults. Recent dye tracing experiments in northern Bexar County has shown a direct, rapid connection from karst features in the Glen Rose Limestone to wells in the recharge and confined zones of the Edwards Aquifer (Johnson et al., 2010).

Groundwater

This area is in a semi-arid environment with average annual rainfall of about 30 to 35 inches per year. Evaporation of 75 to 90 inches per year removes much of this water prior to recharging the aquifers. Many of the rainfall events occur as thermal convection thunderstorms that can produce excessive amounts of precipitation in short periods of time. Some of this water makes its way into the aquifers usually through concentrated areas along creeks and rivers in outcrop areas of the recharge zone.

The Edwards Aquifer is one of the most permeable and productive limestone aquifers in the United States. In the San Antonio region, the aquifer supplies drinking water to more than 1.7 million people and provides habitat for several endangered aquatic species. The Trinity Aquifer plays a lesser role in this region but is none the less designated as a major aquifer of Texas and regionally spans most of central Texas. The stratigraphic, lithologic, and hydrologic characteristics of the rocks in Bexar County are summarized in Figure 2.

Both the Edwards and Trinity Aquifers in this area have karst characteristics with heterogeneous flow, storage and transport of the groundwater via underground conduit systems. Flow in karst aquifers occurs over a wide range of permeability, from flow through the rock matrix (least permeable), flow in planar fractures and bedding planes to turbulent flow through integrated conduit systems (most permeable). Surface landforms commonly seen in this terrain are: 1) recharge features such as solution widened fractures, sinkholes and losing streambed sections, 2) transmission features such as active and relict caves, and 3) discharge features such as permanent and ephemeral springs. In general, most storage occurs in the matrix, while most flow occurs in the conduits. Matrix and conduit components may or may not mix effectively. Thus, some components of the aquifer may have very long residence times and be relatively resistant to surface contamination, while other components of the aquifer may have extremely rapid travel times and be very vulnerable to contamination. The vulnerable portions of the aquifer are also the most productive and the ones that eventually feed the major springs and wells.

In addition to the variability of flow velocities, flow directions are also variable. Flow directions are influenced by hydraulic gradients both regional and local, but are also controlled by the location of conduit systems, which are often influenced by older development that occurred in previous flow regimes. Thus, flow paths may not follow local topography or surface watersheds. It is common for flow in karst aquifers to cross between watershed boundaries. The pattern and direction of flow in karst is often stage dependent, as high water levels can utilize different flow paths and travel in unpredictable directions.

Karst aquifers are, by their nature, extremely vulnerable to contamination. Soils in karst areas tend to be thin and patchy. When eroded by damaging practices, they are slow to be replaced. Thus, the filtration of diffuse recharge afforded by soils is at best low, and is only decreased by human activity. Recharge in karst systems commonly occurs as point recharge into specific karst features, bypassing what little filtration a limited soil zone might afford. Furthermore, a karst flow system is formed by convergent flowpaths that combine to form efficient flow networks. Rapid transportation through integrated flow networks leads to lower residence times, minimizing the opportunity for the die-off of pathogens or the degradation of hazardous chemicals. These efficient flow networks can cover large areas, allowing contaminants to travel long distances very quickly, endangering distant water supplies before problems are identified (Ford and Williams, 2007). Finally, monitoring of contaminant plumes is very difficult due to the anisotropic nature of karst flow systems, where traditional placement of up and down gradient monitoring wells are likely to miss the conduits through which the contaminants are flowing.

Edwards Aquifer

The length of the Edwards Aquifer in the San Antonio region extends approximately 180 miles from the groundwater divide near Brackettville in the west to the groundwater divide north of Kyle in the northeast. The Edwards Aquifer varies in width from 5 to 40 miles from the northern limit of the recharge zone to the southern limit of fresh water. The southern boundary of the aquifer is a gradational zone of increasing salinity from 350 parts per million to over 300,000 parts per million total dissolved solids (TDS).

Two distinctive zones, fresh and saline, can be found in the Edwards Aquifer with a transition area between them. Locally, the point at which TDS reaches 1,000 parts per million is referred to as the "bad-water line" and is the approximate southern extent of potable water. The freshwater zone has gone through extensive changes since deposition whereas the saline zone has retained more of its original depositional lithology. The high productivity of the Edwards Aquifer freshwater zone is a result of dissolution along fractures associated with Balcones faulting. The voids created by the dissolved rock made pathways for the water to move through the limestone. Effective porosity within the freshwater Edwards Aquifer is primarily the result of dissolution of the original rock matrix along bedding planes, joints, and fractures after deposition.

The Edwards Aquifer, as regulated by the TCEQ, has four zones: the Contributing Zone, the Recharge Zone, the Transition Zone and the Confined Zone (Figure 1). In the Contributing Zone, water flows over less permeable bedrock and is routed onto the Recharge Zone. The Contributing Zone is composed of drainage areas and catchments of surface streams that flow over the Recharge Zone. Much of the Contributing Zone lies over the older Glen Rose Formation. The Recharge Zone is a relatively narrow band of outcrops of heavily faulted and karstified Edwards limestone. In the Recharge Zone, surface water flows underground to contribute to the Edwards Aquifer. Water stored in the Recharge Zone as part of the Edwards Aquifer is unconfined. The flow of water is driven by gravity to discharge at water-table springs, to enter deeper flow systems and discharge at artesian springs, or to contribute to the Confined Zone of the Aquifer. The Transition Zone consists primarily of younger bedrock overlying the Confined Zone. These younger and generally less permeable rocks of the Transition Zone overlie and form the upper confining cap to the Artesian Zone of the Edwards Aquifer. While the surface bedrock in the Transition Zone is generally less permeable and karstified than the rocks of the Edwards Group, it is also extensively fractured and faulted by the BFZ, and hosts some high-permeability pathways into the Artesian Zone.

Water levels of the Edwards Aquifer and associated flows of Comal Springs, San Marcos Springs, and other major and minor natural discharge points are affected by the rate of water entering the aquifer (recharge) and the rate of water exiting the aquifer (discharge). Decreased spring discharge and/or degradation of water quality including anthropogenic contamination can adversely affect the health of eight federally-listed endangered or threatened species that depend on adequate minimum flows at Comal and San Marcos Springs for survival.

Recharge occurs from water entering the recharge zone from streams, natural catchments, recharge structures, localized runoff, upland recharge from precipitation events, and potential cross-formational flow from the Trinity Aqufier. Seasonal rainfall over the region ultimately controls the rate of recharge. Discharge occurs from withdrawal of water from wells and from natural springs and seeps. An unknown smaller quantity is discharged to the saline water zone (Maclay 1995). Discharge is greatly affected by water demand and rate of pumping. If recharge is high, the aquifer can sustain higher levels of pumping, while maintaining higher levels of springflows. However, if there is low seasonal recharge followed by reduced rainfall and by high rates of pumping, then aquifer levels will decline with resulting decreased spring discharge.

Estimates of the average annual recharge of the Edwards Aquifer vary according to changes in weather cycles and resulting precipitation over the recharge zone. Maclay (1995) cites an average annual recharge of 635,000 acre-feet. However, Klemt et al. (1979) indicate an average annual recharge of approximately 651,000 acre-feet. Data from the Edwards Aquifer Authority's (EAA) 2008 Hydrogeologic Data Report (Johnson et al., 2009) indicate an average annual recharge of 724,300 acre-feet for the period of record 1934-2008, and an even higher annual average of 991,700 acre-feet during the last ten-year period 1999-2008. Lowest annual recharge (44,000 acre-feet) occurred during 1956 at the peak of the drought of record. Highest recharge (2,486,000 acre-feet) occurred in 1992. Streams losing flow as they cross the Edwards outcrop account for a majority of the recharge to the aquifer (85 %). A much smaller portion is contributed by direct precipitation and localized runoff within the recharge zone (15 %). Rates of infiltration of water carried by the streams across the recharge zone have been estimated by the U.S. Army Corps of Engineers in 1965 to range from 500 to greater than 1,000 cubic feet per second (cfs).

Water discharges the Edwards Aquifer from wells and from natural springs and seeps occurring near geological faults along the Edwards limestone and Balcones Escarpment. Wells are the principal source of water for agricultural, municipal, and industrial uses in the region. Average annual discharge from wells over the period of record 1934-2008 was 310,300 acre-feet (44.6%), in comparison to 385,000 acre-feet (55.4%) from springflow. During droughts, the proportion of well discharge to spring discharge changes considerably. During 1956 at the height of the drought of record, wells contributed 82% of the discharge in comparison to 18% for springs. During the drought of 2008, wells contributed 51% of the total discharge, while spring discharge comprised 49%.

Well discharge has generally increased over the period of record to a point beginning in 1968 and running through 1989 where annual discharge consistently exceeded the average annual recharge (Maclay 1995). Pumping peaked in 1989 at an estimated level of 542,000 acre-feet. Since 1980, as a result of increased pumping, there has been greater fluctuation of springflow with increased time required for recovery, even during a period that recorded the two highest levels of aquifer recharge (1992 and 1987).

In 1993, the Texas Legislature created the Edwards Aquifer Authority (EAA) by passage of the EAA Act to "manage, conserve, preserve, and protect the southern segment of the aquifer and to increase the recharge of, and prevent pollution of water in, the aquifer." Although the legislation was passed in 1993, litigation delayed agency start up by three years, until 1996. In 2007, the Texas Legislature mandated the EAA to allow regular permitted withdrawals from the southern segment of the Edwards Aquifer of up to 572,000 acre-feet per year subject to mandated reductions in pumping of up to 40 percent during critical drought periods. These mandates may be further modified by aquifer management strategies currently being developed as part of a Habitat Conservation Plan also mandated in 2007 by the Texas Legislature, as part of the Edwards Aquifer Recovery Implementation Program.

The groundwater of the Edwards Aquifer is generally known to be of high quality, typically fresh, but hard with an average dissolved solid concentration of less than 500 mg/l (Johnson et al., 2009). However, increased human development throughout the region has created a higher level of pollutants and greater potential for adversely affecting both surface water and groundwater quality. Cooperative efforts between the EAA, U. S. Geological Survey (USGS), and Texas Water Development Board (TWDB) have resulted in a systematic program of water quality monitoring. Each year the EAA measures the quality of water in the aquifer by sampling approximately 80 wells, eight surface water sites, and major spring groups across the region. Sample collection sites are typically selected to provide representative samples of the recharge zone, shallow and deep artesian zone, springs, and surface streams that flow across the recharge zone as well as areas with historical detection of anthropogenic compounds. In 2008, well sampling did not indicate widespread contamination in the aquifer (Johnson et al., 2009). However, elevated nitrate detections (>2 mg/L) were present in 20 of the 81 wells sampled. Metals were detected above a regulatory limit in eight of the 81 wells sampled. Detections of the metals strontium and iron are likely due to naturally occurring sources of these two metals. Strontium detections are typically highest in and close to the saline water part of the aquifer. Iron detections are occasionally high in some parts of the aquifer system. Manganese was unusually high in one well and is scheduled for future monitoring.

Results

Karst Features

Preliminary document reviews of a 1-mile buffer around U. S. 281 revealed numerous caves and karst features in the area (Figure 3). One hundred forty-one geologic and manmade features are documented in this survey of the U.S. 281 highway improvement project area. A complete list of features is given in the geologic assessment table listed before this narrative description section of the GA. Thorough descriptions including photos are given in Appendix B – Descriptions of features located at the U. S. 281 project area. Of the 116 features, 71 scored below 40 points (applying the TCEQ geologic assessment table), indicating a low degree of sensitivity; 30 features scored between 40 and 59 points and are classified with a high degree of sensitivity; 15 features scored at or above 60 points and are interpreted as very highly sensitive karst features with respect to groundwater impact from surface activities (infiltration, contamination, etc.). A karst biologic survey was conducted concurrently with the geologic assessment and these results are presented in a separate report to Jacobs Engineering Group. (Zara, 2010). Locations of all features are presented in Appendices C and D in the soils and geologic maps.

One particular area of high-density caves and karst features was located immediately south of Marshall Road (Figure 4). Here, 10 features were documented, although three (281-088, 281-089, 281-091) eventually merged into one large cave following excavation of the features. All the karst features in this area have developed primarily in a single bedding plane that was exposed from previous down-cutting of the land grade during previous road construction and recent construction performed as part of the U.S. 281 Superstreet project. The large number of significant karst features in this area reflects a high degree of diagenetic alteration of the limestone bedrock in a laterally extensive zone within one strata of rock. Although cave passages were impassible at the back zones of the caves, the areas of karst void development likely extends throughout the local area. Detailed cave maps are presented in Appendix E.

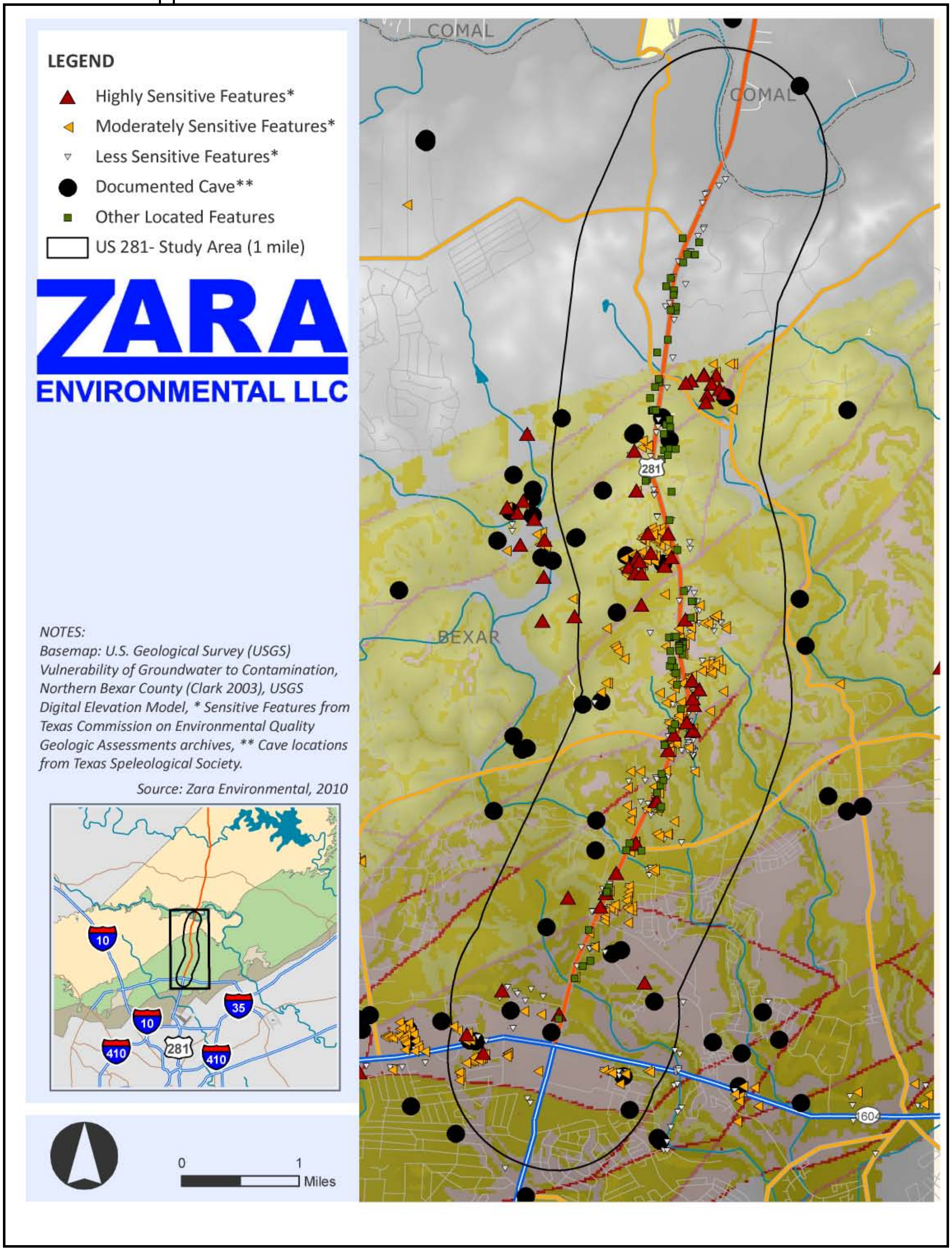

Figure 3. Map of previously recorded karst features in the vicinity of the proposed U.S. 281 highway expansion project The colors on the base map taken from Clark (2003) indicate areas of relative groundwater vulnerability; lighter yellows are less

vulnerable to red being most vulnerable. More information related to the derivation of this base map can be found in Clark (2003).

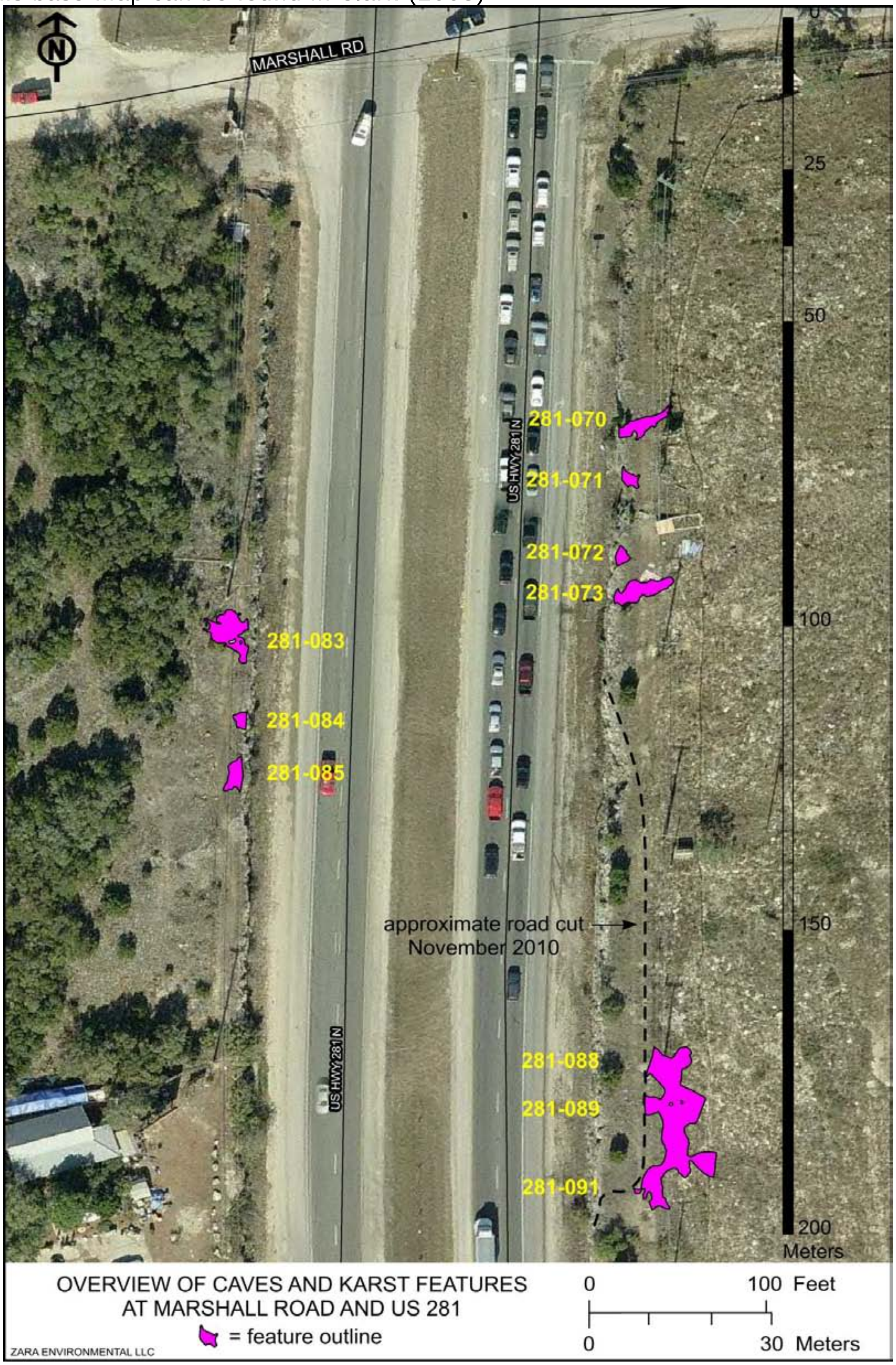

Figure 4. Mapped karst features along U.S. 281 south of Marshall Road.

Manmade Features

This GA was performed along U. S. 281 in a corridor that has undergone extensive previous development. The proposed project area is along the existing ROW of the current highway, which is a substantial 4-lane highway with traffic signals across the entire extent of the EARZ. This previous development, along with associated private, commercial, residential, and public developments within the 500-foot buffer of the proposed expansion of U. S. 281, has produced numerous manmade features encountered during the karst surveys, background study, and other field visits. Only the most significant manmade features observed during walking surveys are identified as specific features in the context of this GA. These are features that are assumed to extend into the bedrock subsurface and not just into the soil or shallow bedrock (such as buried pipelines, water lines, power lines, culverts, etc.) Noted features are wells, deep trenches, and other manmade features, and are described in Appendix B with other features.

Groundwater Wells

The portion of northern Bexar County where U. S. 281 crosses the EARZ has numerous wells used for various applications, including public water supply, commercial/industrial, domestic, and aquifer monitoring (Figure 5). A total of 10 wells were identified from the TWDB well database within a 500-foot buffer of the existing U. S. 281 ROW. Of those wells, some are completed into the Edwards Limestone and others into the Trinity Aquifer in the northern part of the project area. Two are observation well, seven are water supply wells, and one is a test well. All wells are identified on both the soils and geology map plates in Appendices C and D.

Recommendations

The proposed expansion of U. S. 281 in northern Bexar County impacts a significant portion of the Edwards Aquifer, crossing over 12 linear kilometers (7.5 miles) of the EARZ and EACZ. The indirect and cumulative effects of large-scale construction and future increased traffic and associated urbanization of the region are substantial, although not addressed within the scope of this geologic assessment. Construction and operation of the proposed U.S. 281 highway expansion in northern Bexar County has a number of potential environmental impacts related to groundwater quality in the local area and within the region. These possible impacts include water supply contamination associated with construction and operation activities such as increased levels of suspended sediment, dissolved metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and other toxic materials resulting from increased anthropogenic disturbance and activity (Barrett et al., 1995). Infiltration of any of these contaminants into the groundwater system is enhanced in the particular hydrogeologic setting of northern Bexar County, which is karstic in nature. Karst aquifers are well documented to rapidly transmit surface water into the subsurface through systems of enhanced permeability channels that include solution-enlarged fractures or joints, faults, solution cavities, solution sinkholes, collapse sinkholes, caves, or combinations of these features. Special consideration is required to protect the karst groundwater resources from urban development, including that related to the proposed highway U.S. 281 expansion. Direct impacts to groundwater quality are related to the occurrence, density, and type of karst features that exist within the zone of disturbance of projects in karstic environmentally-sensitive zones such as the EARZ, both in the construction and operation phases of highway projects. Hundreds of karst features in the area of the proposed U.S. 281 expansion project have been identified from previous GAs, known caves, and field surveys completed for this report. The high number of features is reflective of the environmental sensitivity of northern Bexar County crossed by U. S. 281, particularly related to potential groundwater contamination possible through discrete karst features.

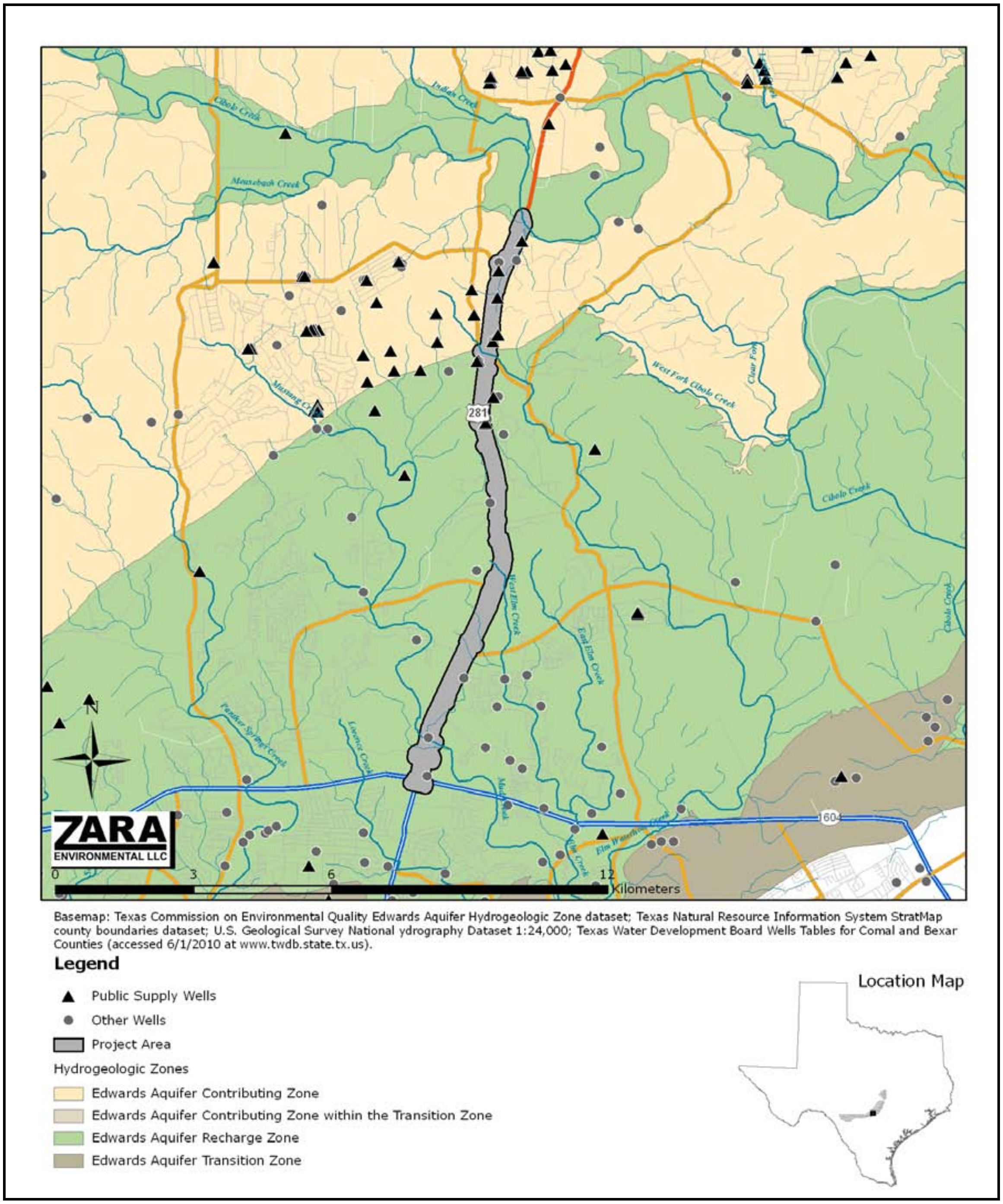

Figure 5. Groundwater wells located in the area around the proposed U. S. 281 expansion project.

The karst survey was performed throughout the entire ROW of the U. S. 281 corridor in the EARZ and portions of EACZ, and in some adjacent properties where access was granted. As per TCEQ guidelines all features with sensitivity values of 40 points or greater should be evaluated for protection in the water pollution abatement plan (WPAP). Additionally, features previously recorded and analyzed by other geological assessments (see Appendix F), and not included in the direct analysis of this GA should be considered as possible sensitive sites, particularly those down gradient of surface water flow (sheetflow, streamflow, etc.). For this reason, particular caution in areas directly affecting all creeks in the project area should be made to prevent water quality degradation from both construction and operation of an expanded highway. In particular, Mud Creek, and Elm Creek pass over the EARZ in the U. S. 281 project area, and karst features and caves are documented in the downstream streambeds of the creeks from the highway. These features could conduct rapid recharge to the aquifer with little to no natural filtration, thus making these downstream segments susceptible to contamination during construction and operation of the highway.

Recent dye tracing studies have been conducted under the direction of the Edwards Aquifer Authority (EAA) (Johnson et al., 2010) and provide good evidence for flowpaths and time of travel in the aquifer. These studies took place near Panther Springs Creek and U. S. 281 (Figure 6) and are directly applicable to evaluation of sensitivity of the EARZ in the area near the proposed highway project. Four phases of tracing using non-toxic fluorescent dyes were performed through injection sites in six caves and at an additional site that is a soil covered inter-stream location with no visible karst features. Water was sampled for the detection of the dyes in 32 public and private wells located in the general vicinity of Panther Springs Creek near Loop 1604 and U.S. 281 (Figure 6).

The path that the dyes took from injection point to receptor crossed under the Loop 1604 area just east of the Blanco Road intersection. The potential straight-line flow velocities measured from the testing ranged from a low of 43 feet per day to a high of 17,400 feet per day. The large discrepancies in velocities can be attributed to whether a monitored well is located in the vicinity of karst conduit or flow path that might directly channel the dye to a particular location and dye attenuation times in the vadose zone at injection sites. The hydrologic conditions before, during and after dye injections potentially impact both groundwater velocity and direction of groundwater flow. Several mapped faults are located between injection and the monitored receptor wells. The results from the traces indicate that these faults did not interfere or redirect the flow path between receptor and injection locations. The apparent flow direction was perpendicular to the faults and generally parallel to the surface direction along the creek. Additionally, some of the injections were in caves predominantly in the upper Glen Rose and were detected downstream in wells completed into the Edwards Aquifer. The location of one dye injection was in an inter-stream location and was slowly flushed with water over a two-month period in an area with no observable karst features. The dye was detected in two wells, which demonstrated the potential vulnerability of the recharge zone even in areas that are not known to have mapped caves or other karst features.

Both the modeled and traced flowpaths in northern Bexar County have significant implications to construction and operation of the proposed U. S. 281 project. The tracer results indicate that contaminants introduced through discrete karst features and even open ground potentially reach water supply wells at extremely rapid rates. Modeled flowpaths show water entering the aquifer in northern Bexar County flows directly to Comal Springs, which provides habitat to endangered species.

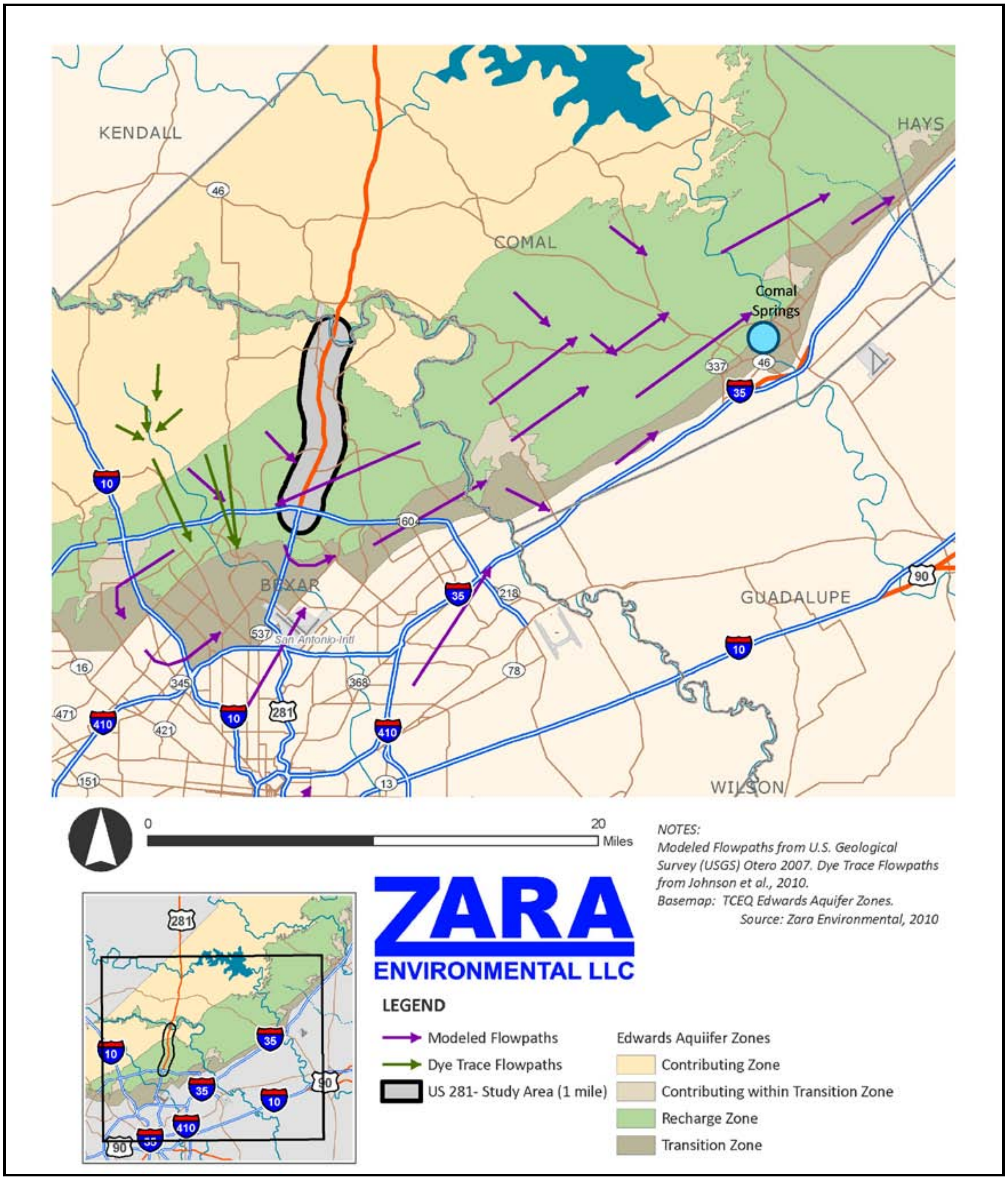

Figure 6. Modeled flowpaths and direct flowpaths identified from dye tracer studies in the vicinity of U. S. 281.

There are many difficulties when performing a GA in areas that have been significantly altered by previous anthropogenic activity such as U. S. 281 in northern Bexar County. The natural land surface was previously altered in many areas from features with pavement, graded fill, asphalt, and buildings. However, significant areas of vertical outcrops of Edwards Limestone were exposed along U. S. 281 and Loop 1604 during initial construction of both of these highways, revealing intermittent cross-sections of the subsurface. This allowed for quantitative assessment of the degree of diagenetic alteration from faulting, fracturing, dissolution, and mineralization in the exposed roadcuts (Meyer and Gary, 2010). Although significant heterogeneity of feature occurrence was identified, a reasonably high percentage of feature density was identified that could be extrapolated throughout the Edwards Limestone (Person and Kainer Fms.) outcrops. For this reason, the most conservative approach to protecting water quality in the EARZ crossed by U. S. 281 would be to implement as many environmental safeguards as possible throughout the project area in the EARZ in addition to site-specific protection for all identified sensitive features, particularly the 45 features with sensitivity values over 40 and especially those 15 with values over 60. An intensive water quality monitoring program with emphasis on storm water event-based sampling should be implemented to identify any immediate and long-term effects on Edwards Aquifer water quality degradation resulting from construction and operation of the proposed U. S. 281 expansion project.

Several mechanisms are possible for introducing contaminants into the groundwater system in urbanized areas. Cumulative buildup of metals and organic compounds along heavily used highways is the most persistent source of pollutants (Van Metre et al., 2000). Large spills from storage tanks on vehicles could possibly occur during accidents, and is listed as a direct threat to water quality in the Edwards Aquifer (Johnson et al., 2009). Gasoline and diesel fuels are the most common hazardous materials carried along the project area. An accidental release of a large quantity of hazardous material to a sensitive recharge feature is a low-probability event, however it has the potential to adversely impact the major regional groundwater source. PAH compounds and heavy metal elements are harmful hydrophobic contaminants shown to accumulate with vehicle traffic on highways, and become associated with sediment particles. Storm events wash the contaminated particles into surface streams (Van Metre et al., 2003; Mahler et al., 2006), and in the specific setting of the Edwards Aquifer, can be rapidly transmitted directly into the groundwater system. This could allow for a build-up of PAHs in the aquifer that could present long-term adverse effects on drinking water supplies and eventually make it to springs through direct transfer or re-suspension (Massei et al., 2003).

The implementation of some best management practices (BMPs) can have a positive effect to control of contamination to the water system, and it has been shown that without strict adherence of efficient BMPs, highway construction and operation has a large negative impact on water quality, including groundwater in karst zones (Barrett et al., 1995; Donaldson, 2004). These contaminants are normally conveyed by runoff from the roadway primarily during the “first flush”, or the first inch of rain. The first flush carries with it concentrations of pollutants that have accumulated during periods of dry weather between storms, and is strongly correlated with percent land use (Van Metre et al., 2003). TCEQ Edwards Rules (Chapter 213) require the construction and maintenance of permanent water quality controls to remove suspended solids from runoff after construction for the life of the roadway. These water quality controls include filter strips, sand filters, and extended detention basins. The implementation of these engineered water-quality control structures, or

BMPs are put in place to help offset potential impacts through short-term retention or filtration prior to discharging to streams. By utilizing suitable BMPs for filtering storm water, the potential for groundwater quality degradation may be reduced, but not eliminated. Other water quality mitigation practices include: defining extent of contamination plumes, predicting groundwater flow paths, building and maintaining effective monitoring networks, and treating contaminated water.

Personnel

Marcus O. Gary, Ph.D. directed the geologic assessment on this project. Marcus is a State of Texas licensed geologist (No. 10386) and hydrogeologist specializing in investigating karst forming processes and the implications of karst geology for natural resource management. Marcus received an Associate of Science degree in Marine Technology at the College of Oceaneering, a B.S. degree in hydrogeology and environmental geology at the University of Texas at Austin (UT), and completed his doctorate at UT on defining volcanogenic karst related to deep cave development in 2009. His research has been internationally recognized for investigating one of the world's deepest underwater sinkholes and interpreting the geologic mechanisms that formed the karst system. For eight years he worked in the Texas Water Science Center of the U.S. Geological Survey, performing numerous tasks related to water resources. Projects included developing methods to quantify spring flow using acoustic technology, monitoring discharge and water chemistry parameters at springs, assisting with a geochemical investigation of the Barton Springs Segment of the Edwards Aquifer, providing diving support for coring and karst monitoring projects, serving as a dive safety officer for the Central Region, and designing and implementing a variety of continuous monitoring projects at locations across Texas. His work at Zara since 2007 includes geologic assessments, drainage basin delineation, and dye tracing.

Jean K. Krejca, Ph.D. performed field work and edited this report. She is a biologist specializing in karst fauna. Jean has a Bachelor's degree in Zoology, and a Ph.D. in Evolution, Ecology and Behavior from the University of Texas. Her dissertation work focused on cave-adapted aquatic fauna, biogeography and hydrology of Texas and North Mexico. Since 1991 she has worked as a cave biologist and her experience in that area spans across the United States (California, Texas, Nevada, Illinois, Missouri, Indiana, Tennessee, North and South Carolina) as well as Mexico, Belize, Thailand, and Malaysia. She has published extensively on these studies. Her Texas cave biology experience started in 1997 and includes detailed collections of aquatic cave fauna for research, monitoring for endangered species, and working as a Karst Invertebrate Specialist for the U.S. Fish and Wildlife Service. In 2003 she co-founded Zara Environmental LLC, which offers land management and endangered species permit consultation in addition to conducting various research projects. She has been involved with a variety of public outreach efforts including presentations, leading field trips, and cave biology photography. She holds USFWS Endangered Species Permit TE028652-0.

Krista McDermid holds a Master's degree in Wildlife Ecology from Texas State University in San Marcos, where she studied the Common Musk Turtle, *Sternotherus odoratus*. She also holds a bachelor's degree in Evolution, Ecology and Behavior from The University of Texas at Austin, where she worked on behavioral and genetic development of the zebra fish, *Danio rerio.* Krista has worked as a biologist for Texas Parks & Wildlife Department monitoring white-winged dove migration and population, and the City of Austin assisting with a mark-recapture study on the Jollyville Plateau

Salamander, *Eurycea tonkawae*. Krista is a GIS technician; she received her certification in ArcView 3.x in 2005, and completed the postbaccalaureate certification program in geographic information systems through Penn State University in 2010. She has worked with Zara since 2007 and in that time has participated in numerous habitat surveys for listed karst invertebrates, cave fauna surveys, karst feature surveys, presence/absence surveys and biological monitoring for listed karst invertebrates. She has also conducted aquatic macro-invertebrate habitat and presence/absence surveys for aquifer species in Hays, Bexar, Uvalde and Medina Counties.

N. Cass Meyer assisted with the Geologic Assessment in the field and helped prepare the final report, including the roadcut analysis. Cass is working towards his Professional Geoscientist license, and has his Bachelor of Science in Geology from the University of Texas at Austin. Cass has been involved with numerous subsurface and groundwater modeling projects throughout Texas focusing on the Upper and lower Cretaceous, and has recently begun learning caving techniques from Zara personnel.

Kathleen O'Connor assisted with the karst feature survey for this project. Kathleen is an ecologist and has worked on Central Texas endangered species for over five years. She earned her M.S. in Wildlife Ecology from Texas State University in 2003, and subsequently worked as a Natural Resources Specialist at Travis County's Balcones Canyonlands Preserve. She has extensive experience working with Golden-cheeked warblers and Black-capped vireos, including presence/absence surveys and territory mapping. She has also conducted numerous surveys for karst invertebrate and salamander species. She holds a USFWS permit covering endangered karst invertebrates and birds.

Peter Sprouse directed the karst feature survey for this project. He has been exploring and studying caves since 1970, having led the exploration of Sistema Purificación in Mexico, one of the longest and deepest caves in the world. He began collecting cave fauna for study by taxonomists in 1977, and has nine species named in his honor. He attended the University of Texas at Austin in 1974 as geology major, and since 1991 he has worked professionally in the fields of cave biology, land management, and cartography. He co-founded Zara Environmental LLC in 2003 and currently manages over 90 caves in central Texas, conducting fire ant control and building cave gates. His experience in conducting karst surveys for invertebrate cave fauna habitat is very extensive. He is an NSS Fellow and was presented with the prestigious Lew Bicking Award and is a multiple medal winner in NSS Cartographic Salons. He is a director of the Texas Speleological Survey and serves on the Balcones Canyonlands Preserve Scientific Advisory Committee Karst Subcommittee. He holds US Fish and Wildlife Service Endangered Species Permit number TE014168-0 and Texas Department of Agriculture Pest Control License number 0362274.

Sarah J. "Saj" Zappitello assisted with this Geologic Assessment in the field and helped prepare the final report. Saj is a hydrogeologist specializing in karst and groundwater systems. She earned a B.S. in hydrogeology and environmental geology from the University of Texas, where as a research assistant she published on the isotopic constraints and research applications of isotope ratios in aquifer studies. After graduating, Saj worked as a technician for the USGS, then became a hydrogeologist with INTERA Inc. She is currently a hydrogeologist with Zara Environmental LLC where her projects include aquifer dye traces, hydrogeological studies, and karst feature surveys and assessments. In addition to her education and professional background, Saj gains valuable experience recreationally caving and volunteering for non-profit institutions like the Texas Cave Management Association and Proyecto Espeleológico Purificación. Previous efforts with these groups involved exploring and surveying new caves, searching for and mapping karst features, and leading beginner trips to expose the public to karst hydrogeology. She holds a USFWS endangered species permit (TE208531-0) covering geologic research in central Texas caves.

Literature Cited

Barrett, M.E., 1999. Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices: TCEQ, Field Operations Divisions, RG-348.

Barrett, M. E., Malina, Jr., J. F., Charbeneau, R. J., Ward, G. H., 1995, Effects of highway construction and operation on water quality and quantity in an ephemeral stream in the Austin, Texas area, Center for Research in Water Resources, The University of Texas at Austin, Technical Report CRWR 262, 56 pp.

Donaldson, B. M., 2004, Highway runoff in areas of karst topography, Report for the Virginia Transportation Research Council, 17 p.

Ford, D., & Williams, P., 2007, *Karst Hydrogeology and Geomorphology.* Hoboken: John Wiley & Sons, Ltd., 562 p.

Johnson, S., Schindel, G., & Hoyt, J., 2009, Water quality trends analysis of the San Antonio segment, Balcones Fault Zone Edwards Aquifer. Edwards Aquifer Authority Report No. 09-03, 48 p.

Johnson, S., Schindel, G., Veni, G., 2010, Tracing Groundwater Flowpaths in the Edwards Aquifer Recharge Zone, Panther Springs Creek Basin, Northern Bexar County, Texas, Edwards Aquifer Authority Report No. 10-01, 112 p.

Klemt, W. B., Knowles, T. R., Elder, G. R., & Sieh, T. W., 1979, Ground-water resources and model applications for the Edwards (Balcones fault zone) aquifer in the San Antonio region: Texas, Texas Department of Water Resources Report 239, 94 p.

Lingren, R. J., Dutton, A. R., Hovorka, S. D., Worthington, S. R. H., Painter, S., 2004, Conceptualization and Simulation of the Edwards Aquifer, San Antonio Region, Texas, U. S. Geological Survey Scientific Investigations Report 2004-5277, 143 p.

Maclay, R. W., 1995, Geology and hydrology of the Edwards Aquifer in the San Antonio area, Texas. United States Geological Survey , Water Resources Investigations Report 95-4186, 69 p., 12 sheets.

Maclay, R. W., Small, T. A., 1976, Progress report on geology of the Edwards aquifer, San Antonio area, Texas, and preliminary interpretation of borehole geophysical and laboratory data on carbonate rocks. United States Geological Survey Open-File Report 76-627, 65 p.

Maclay, R. W., Small, T. A., 1984, Carbonate geology and hydrology of the Edwards aquifer in the San Antonio area, Texas. United States Geological Survey Open-File Report 83-537, 72 p.

Mahler, B. J., Van Metre, P. C., Wilson, J. T., Guilfoyle, A. L., Sunvision, M. W., 2006, Concentrations, loads, and yields of particle-associated contaminants in urban creeks, Austin, Texas, 1999-2004, U. S. Geological Survey Scientific Investigations Report 2006-5262, 107 p.

Massei, N., Wang, H. Q., Dupont, J. P., Rodet, J., Laignel, B., 2003, Assessment of direct transfer and resuspension of particles during turbid floods at a karstic spring, Journal of Hydrology, no. 275, p. 109-121.

Meyer, N.C., Gary, M.O., Spatial density analysis of karst diagenesis and aquifer recharge sensitivity, Edwards Aquifer, Texas, Geological Society of America Abstracts with Programs, 2010 Joint Annual Meeting, Denver, Colorado.

Reeves, R., 1967, Groundwater resources of Kendall County, Texas, Texas Water Development Board Report 60, 90 p.

Rose, P.R., 1972, Edwards Group, surface and subsurface, central Texas: Austin, University of Texas, Bureau of Economic Geology, Report of Investigations 74, 198 p.

Stricklin, F. L., Smith, C. I., & Lozo, F. E., 1971, Stratigraphy of Lower Cretaceous Trinity deposits of cen¬tral Texas. Bureau of Economic Geology Report of Investigations 71, 63 p.

Texas Commission on Environmental Quality (TCEQ), 2004, Instructions to Geologists for Geologic Assessments on the Edwards Aquifer Recharge/Transition Zone. TCEQ RG-0508, 34 p., revised October 1, 2004.

Texas Natural Resources Information System (TNRIS), 2010, Geologic Atlas of Texas, http://www.tnris.org/data/Geology/GeologicDatabaseofTexas.zip, accessed February 15, 2010.

United States Department of Agriculture (USDA), 2010, Natural Resources Conservation Service, Soil Survey staff, 2008, Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ , accessed April 8, 2010.

United States Fish and Wildlife Service (USFWS), 2006, Section 10(a)(1)(A) Scientific Permit Requirements for Conducting Presence/Absence Surveys for endangered karst invertebrate species, 21 p., revised March 8, 2006, USFWS Ecological Services Field Office, Austin, Texas.

USGS SIM 2873, Blome, C.D., Faith, J.R., Pedraza, D.E., Ozuna, G.B., Cole, J.C., Clark, A.K., Small, T.A., and Morris, R.R., compilers, 2005, Geologic map of the Edwards aquifer recharge zone, southcentral Texas: U.S. Geological Survey Scientific Investigations Map 2873, scale 1:200,000.

Van Metre, P. C., Mahler, B. J., Furlong, E. T., 2000, Urban sprawl leaves its PAH signature, Environmental Science and Technology, no. 34, p. 4064-4070.

Van Metre, P. C., Wilson, J. T., Harwell, G. R., Gary, M. O., Heitmeuller, F. T., Mahler, B. J., 2003, Occurrence, trends, and sources in particle-associated contaminants in selected streams and lakes in Fort Worth, Texas, U. S. Geological Survey Water-Resources Investigations Report 03-4169, 154 p.

Veni, G., and J. Reddell, 2002, Protocols for Assessing Karst Features for Endangered Invertebrate Species. Report by George Veni and Associates, San Antonio, Texas. 7pp.

Zara, 2010, Draft karst invertebrate technical report for U. S. 281 from Loop 1604 to Borgfeld Road, Bexar County, Texas, Report prepared for Jacobs Engineering Group, Austin, Texas, 143 pp.

GEOLOGICAL ASSESSMENT FOR
U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD,
BEXAR COUNTY, TEXAS

APPENDIX A:
SOIL DESCRIPTIONS

Appendix A: Soil Descriptions

BrE—Brackett gravelly clay loam, 12 to 20 percent slopes

Map Unit Setting

- Elevation: 1,000 to 2,000 feet
- Mean annual precipitation: 22 to 32 inches
- Mean annual air temperature: 64 to 70 degrees F
- Frost-free period: 220 to 240 days

Map Unit Composition

- Brackett and similar soils: 100 percent

Description of Brackett

Setting

- Landform: Ridges
- Landform position (two-dimensional): Backslope, footslope, shoulder
- Landform position (three-dimensional): Side slope
- Down-slope shape: Concave
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 12 to 20 percent
- Depth to restrictive feature: 6 to 20 inches to paralithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat):Moderately low to high (0.06 to 1.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 90 percent
- Gypsum, maximum content: 5 percent
- Available water capacity: Very low (about 1.5 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Steep Adobe 29-35" PZ (R081CY362TX)

Typical profile

- 0 to 4 inches: Gravelly clay loam
- 4 to 12 inches: Gravelly clay loam
- 12 to 30 inches: Bedrock

BtE—Brackett-Eckrant association, 20 to 60 percent slopes

Map Unit Setting

- Elevation: 1,000 to 2,400 feet
- Mean annual precipitation: 22 to 32 inches
- Mean annual air temperature: 64 to 70 degrees F
- Frost-free period: 210 to 240 days

Map Unit Composition

- Brackett and similar soils: 60 percent
- Eckrant and similar soils: 40 percent

Description of Brackett

Setting

- Landform: Ridges
- Landform position (two-dimensional): Backslope, footslope
- Landform position (three-dimensional): Side slope, base slope
- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 20 to 60 percent
- Depth to restrictive feature: 6 to 20 inches to paralithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat):Moderately low to high (0.06 to 1.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 90 percent
- Gypsum, maximum content: 5 percent
- Available water capacity: Very low (about 1.5 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Steep Adobe 29-35" PZ (R081CY362TX)

Typical profile

- 0 to 4 inches: Gravelly clay loam
- 4 to 12 inches: Gravelly clay loam
- 12 to 30 inches: Bedrock

Description of Eckrant

Setting

- Landform: Ridges
- Landform position (two-dimensional): Backslope, footslope
- Landform position (three-dimensional): Base slope, side slope

- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 20 to 60 percent
- Depth to restrictive feature: 8 to 20 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat):Moderately low to moderately high (0.06 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 8 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Very low (about 1.6 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Steep Rocky 29-35" PZ (R081CY363TX)

Typical profile

- 0 to 10 inches: Cobbly clay loam
- 10 to 18 inches: Extremely stony clay
- 18 to 25 inches: Bedrock

Ca—Anhalt clay, 0 to 1 percent slopes

Map Unit Setting

- Elevation: 1,200 to 2,200 feet
- Mean annual precipitation: 25 to 32 inches
- Mean annual air temperature: 63 to 70 degrees F
- Frost-free period: 230 to 240 days

Map Unit Composition

- Anhalt and similar soils: 100 percent

Description of Anhalt

Setting

- Landform: Plains
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 0 to 1 percent
- Depth to restrictive feature: 20 to 40 inches to paralithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 15 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Low (about 4.8 inches)

Interpretive groups

- Land capability (nonirrigated): 2s
- Ecological site: Deep Redland 29-35" PZ (R081CY358TX)

Typical profile

- 0 to 7 inches: Clay
- 7 to 32 inches: Clay
- 32 to 50 inches: Bedrock

Cb—Crawford and Bexar stony soils

Map Unit Setting

- Elevation: 400 to 1,900 feet
- Mean annual precipitation: 26 to 34 inches
- Mean annual air temperature: 64 to 68 degrees F
- Frost-free period: 230 to 270 days

Map Unit Composition

- Crawford and similar soils: 64 percent
- Bexar and similar soils: 36 percent

Description of Crawford

Setting

- Landform: Plains
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 0 to 3 percent
- Surface area covered with cobbles, stones or boulders: 1.0 percent
- Depth to restrictive feature: 20 to 40 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 2 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Sodium adsorption ratio, maximum: 2.0
- Available water capacity: Low (about 4.7 inches)

Interpretive groups

- Land capability (nonirrigated): 2e
- Ecological site: Deep Redland 29-35" PZ (R081CY358TX)

Typical profile

- 0 to 8 inches: Stony clay
- 8 to 34 inches: Stony clay
- 34 to 50 inches: Bedrock

Description of Bexar

Setting

- Landform: Plains
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 0 to 5 percent
- Depth to restrictive feature: 20 to 40 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Low (about 3.3 inches)

Interpretive groups

- Land capability (nonirrigated): 4s
- Ecological site: Redland 29-35" PZ (R081CY361TX)

Typical profile

- 0 to 18 inches: Cobbly clay loam
- 18 to 27 inches: Cobbly clay
- 27 to 32 inches: Bedrock

Kr—Krum clay, 1 to 5 percent slopes

Map Unit Setting
- Elevation: 600 to 1,300 feet
- Mean annual precipitation: 26 to 36 inches
- Mean annual air temperature: 63 to 70 degrees F
- Frost-free period: 230 to 250 days

Map Unit Composition
- Krum and similar soils: 100 percent

Description of Krum

Setting
- Landform: Stream terraces
- Landform position (three-dimensional): Tread, riser
- Down-slope shape: Concave
- Across-slope shape: Linear
- Parent material: Alluvium derived from limestone

Properties and qualities
- Slope: 1 to 5 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 50 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Sodium adsorption ratio, maximum: 3.0
- Available water capacity: High (about 9.3 inches)

Interpretive groups
- Land capability (nonirrigated): 3e
- Ecological site: Clay Loam 29-35" PZ (R081CY357TX)

Typical profile
- 0 to 18 inches: Clay
- 18 to 50 inches: Clay
- 50 to 62 inches: Clay

Or—Orif soils, 0 to 1 percent slopes, frequently flooded

Map Unit Setting

- Elevation: 750 to 2,000 feet
- Mean annual precipitation: 18 to 30 inches
- Mean annual air temperature: 66 to 70 degrees F
- Frost-free period: 220 to 270 days

Map Unit Composition

- Orif and similar soils: 85 percent
- Minor components: 15 percent

Description of Orif

Setting

- Landform: Flood plains
- Down-slope shape: Linear
- Across-slope shape: Concave
- Parent material: Alluvium derived from limestone

Properties and qualities

- Slope: 0 to 1 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: Frequent
- Frequency of ponding: None
- Calcium carbonate, maximum content: 90 percent
- Available water capacity: Low (about 3.6 inches)

Interpretive groups

- Land capability (nonirrigated): 6s
- Ecological site: Loamy Bottomland 29-35" PZ (R081CY561TX)

Typical profile

- 0 to 20 inches: Gravelly loamy sand
- 20 to 40 inches: Extremely gravelly sand
- 40 to 80 inches: Coarse sand

Minor Components

Unnamed, minor components

- Percent of map unit: 14 percent

Unnamed, hydric minor components

- Percent of map unit: 1 percent
- Landform: Depressions

Pt—Pits and Quarries, 1 to 90 percent slopes

Map Unit Setting

- Elevation: 20 to 8,750 feet
- Mean annual precipitation: 9 to 56 inches
- Mean annual air temperature: 54 to 73 degrees F
- Frost-free period: 180 to 350 days

Map Unit Composition

- Pits: 100 percent

Description of Pits

Interpretive groups

- Land capability (nonirrigated): 8s

Typical profile

- 0 to 80 inches: Variable

TaB—Eckrant cobbly clay, 1 to 5 percent slopes

Map Unit Setting

- Elevation: 1,000 to 2,400 feet
- Mean annual precipitation: 22 to 32 inches
- Mean annual air temperature: 66 to 70 degrees F
- Frost-free period: 210 to 240 days

Map Unit Composition

- Eckrant and similar soils: 100 percent

Description of Eckrant

Setting

- Landform: Ridges
- Landform position (two-dimensional): Shoulder
- Landform position (three-dimensional): Side slope
- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 1 to 5 percent
- Surface area covered with cobbles, stones or boulders: 3.0 percent
- Depth to restrictive feature: 8 to 20 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 8 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Very low (about 1.6 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Low Stony Hill 29-35" PZ (R081CY360TX)

Typical profile

- 0 to 10 inches: Cobbly clay
- 10 to 18 inches: Extremely stony clay loam
- 18 to 25 inches: Bedrock

TaC—Eckrant cobbly clay, 5 to 15 percent slopes

Map Unit Setting

- Elevation: 1,000 to 2,400 feet
- Mean annual precipitation: 22 to 32 inches
- Mean annual air temperature: 66 to 70 degrees F
- Frost-free period: 210 to 240 days

Map Unit Composition

- Eckrant and similar soils: 100 percent

Description of Eckrant

Setting

- Landform: Ridges
- Landform position (two-dimensional): Shoulder
- Landform position (three-dimensional): Side slope
- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 5 to 15 percent
- Surface area covered with cobbles, stones or boulders: 3.0 percent
- Depth to restrictive feature: 8 to 20 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 8 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Very low (about 1.6 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Low Stony Hill 29-35" PZ (R081CY360TX)

Typical profile

- 0 to 10 inches: Cobbly clay
- 10 to 18 inches: Extremely stony clay loam
- 18 to 25 inches: Bedrock

TaD—Eckrant-Rock outcrop complex, 15 to 60 percent slopes

Map Unit Setting

- Elevation: 300 to 8,700 feet
- Mean annual precipitation: 10 to 35 inches
- Mean annual air temperature: 52 to 73 degrees F
- Frost-free period: 120 to 320 days

Map Unit Composition

- Eckrant and similar soils: 75 percent
- Rock outcrop: 17 percent
- Minor components: 8 percent

Description of Eckrant

Setting

- Landform: Ridges
- Landform position (two-dimensional): Backslope, footslope
- Landform position (three-dimensional): Base slope, side slope
- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Residuum weathered from limestone

Properties and qualities

- Slope: 15 to 60 percent
- Surface area covered with cobbles, stones or boulders: 5.0 percent
- Depth to restrictive feature: 8 to 20 inches to lithic bedrock
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat):Moderately low to moderately high (0.06 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: None
- Frequency of ponding: None
- Calcium carbonate, maximum content: 8 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Available water capacity: Very low (about 1.6 inches)

Interpretive groups

- Land capability (nonirrigated): 7s
- Ecological site: Steep Rocky 29-35" PZ (R081CY363TX)

Typical profile

- 0 to 10 inches: Cobbly clay
- 10 to 18 inches: Extremely stony clay
- 18 to 25 inches: Bedrock

Description of Rock Outcrop

Setting

- Landform: Ridges
- Landform position (two-dimensional): Backslope, footslope
- Landform position (three-dimensional): Base slope, side slope
- Down-slope shape: Convex
- Across-slope shape: Convex
- Parent material: Limestone

Properties and qualities

- Slope: 15 to 90 percent
- Depth to restrictive feature: 0 to 2 inches to lithic bedrock
- Capacity of the most limiting layer to transmit water (Ksat):Moderately low to very high (0.06 to 19.98 in/hr)

Interpretive groups

- Land capability (nonirrigated): 8s

Typical profile

- 0 to 80 inches: Bedrock

Minor Components

Unnamed, minor components

- Percent of map unit: 8 percent

Tf—Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded

Map Unit Setting

- Elevation: 250 to 1,700 feet
- Mean annual precipitation: 25 to 42 inches
- Mean annual air temperature: 64 to 68 degrees F
- Frost-free period: 220 to 270 days

Map Unit Composition

- Tinn and similar soils: 60 percent
- Frio and similar soils: 39 percent
- Minor components: 1 percent

Description of Tinn

Setting

- Landform: Flood plains, flood plains
- Microfeatures of landform position: Circular gilgai, circular gilgai
- Down-slope shape: Linear
- Across-slope shape: Concave
- Parent material: Clayey alluvium of holocene age derived from mixed sources

Properties and qualities

- Slope: 0 to 1 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Moderately well drained
- Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: Frequent
- Frequency of ponding: None
- Calcium carbonate, maximum content: 25 percent
- Gypsum, maximum content: 2 percent
- Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
- Sodium adsorption ratio, maximum: 6.0
- Available water capacity: High (about 9.7 inches)

Interpretive groups

- Land capability (nonirrigated): 5w
- Ecological site: Clayey Bottomland 28-40" PZ (R086AY198TX)

Typical profile

- 0 to 8 inches: Clay
- 8 to 65 inches: Clay
- 65 to 80 inches: Clay

Description of Frio

Setting

- Landform: Flood plains
- Down-slope shape: Linear
- Across-slope shape: Linear
- Parent material: Loamy alluvium of holocene age derived from mixed sources

Properties and qualities

- Slope: 0 to 1 percent
- Depth to restrictive feature: More than 80 inches
- Drainage class: Well drained
- Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
- Depth to water table: More than 80 inches
- Frequency of flooding: Frequent
- Frequency of ponding: None
- Calcium carbonate, maximum content: 40 percent
- Sodium adsorption ratio, maximum: 2.0
- Available water capacity: High (about 10.2 inches)

Interpretive groups

- Land capability (nonirrigated): 5w
- Ecological site: Loamy Bottomland 28-40" PZ (R086AY203TX)

Typical profile

- 0 to 30 inches: Silty clay loam
- 30 to 50 inches: Silty clay loam
- 50 to 80 inches: Clay loam

Minor Components

Unnamed, hydric minor components

- Percent of map unit: 1 percent
- Landform: Sloughs

GEOLOGICAL ASSESSMENT FOR
HIGHWAY 281,
BEXAR COUNTY, TEXAS

APPENDIX B:
FEATURE DESCRIPTIONS

Appendix B: Feature Descriptions

Field ID	Description	Photo
281-001	This feature is a water well with a 0.15 m (0.5 ft) diameter.	
281-002	This is a spring that lies just outside of the eastern US 281 right of way, south of Borgfeld Road. Part of the spring pool is within the ROW, but the apparent spring source is on private land where right of entry was not granted. The spring appears to emerge from sediments, with no obvious single source. The spring pool measured 2 by 7 m (6.6 by 23 ft) when first recorded on 26 February 2010. Surface flow from the spring sank into sediments just downstream of the pool.	
281-003	This spring is located along the eastern US 281 ROW just south of Borgfeld Road. There are five distinct spring sources; four of these emerge from sediment in an area that is 7 m (23 ft) long by 2 m (6.6 ft) wide by 0.3 m (1 ft) deep. The fifth emerges from a weep-hole pipe at the base of a concrete skirt constructed as part of the highway. The source of this water is unknown. The spring pool is bisected by the ROW limit.	

281-004	This is a closed depression that is situated on private property where right of entry was not granted. It is just across a fence line at the base of a persimmon tree. The feature is 0.7 m (2.3 ft) long, 0.5 m (1.6 ft) wide, and 0.25 m (0.8 ft) deep. It may be a solutional sinkhole, or it could be an animal burrow. No right of entry was available for further evaluations.	
281-005	This non-karst closed depression is mostly in the ROW, but is crossed by a fence and is partially on private property. A hackberry tree is growing out of one side of it. It is 1.5 m (4.9 ft) long, 0.7 m (2.3 ft) wide, and 0.2 m (0.7 ft) deep. Excavation was conducted on 10 September 2010 for 1.5 person-hours and 0.15 m^3 (5.3 ft^3) of material was removed. It was determined to be a burrow made by animals exploiting the roots of the hackberry tree rather than a karst feature. Post-excavation dimensions were 1.5 m (4.9 ft) long, 1 m (3.8 ft) wide, and 0.5 m (1.6 ft) deep.	
281-006	This solution enlarged fracture is in the road cut on the west side of US 281. The entrance to it is 0.8 m (2.6 ft) wide, 0.4 m (1.3 ft) high, and it extends into the road cut for 1 m (3.3 ft). It contains no infill.	

281-007	This solution cavity is situated in the road cut on the west side of US 281. The entrance to the feature is 0.7 m (2.3 ft) wide, 0.5 m (1.6 ft) high, and it extends into the road cut for 0.5 m (1.6 ft). It is an enlarged bedding plane with no infill.	
281-008	This solution cavity is an enlarged bedding plane in the road cut on the west side of US 281. The entrance is 0.4 m (1.3 ft) wide, 0.1 m (0.3 ft) high, and it extends into the road cut for at least 1.5 m (4.9 ft). It is developed in pulverulitic limestone and has coarse and silty infill.	
281-009	This is a pair of closed depressions on private property on the west side of US 281. The feature measures 1.5 by 1 m (4.9 ft by 3.8 ft), and is 0.3 m (1 ft) deep. It may be karstic in origin, or it may have an anthropogenic origin related to a nearby natural gas pipeline. Excavation would be needed to make that determination, and was recommended. Right of entry for excavation purposes was not granted.	
281-010	This is a seep spring located on private property on the west side of US 281. It flows from the travertine covered base of a 3 m (9.8 ft) tall cliff in an area that is 2 m (6.6 ft) long by 1 m (3.3 ft) wide, but it does not have an identifiable portal. A small amount of water was flowing from it when assessed on 1 March 2010.	

281-011	This non-karst closed depression is located on private property between a house and some storage units. When first located it was 1.5 m in diameter and 0.7 m deep, and filled with loose rocks and snakes. Excavation was recommended to determine its origin. This was conducted on 10 August 2010. During this excavation effort, 9.25 person-hours of effort were expended and 1.25 m^3 of material was removed. This resulted in a rectangular depression 2.5 m (8.2 ft) long, 1.5 m (4.9 ft) wide, and 1 m (3.3 ft) deep, with a floor of hard-packed soil. Trash was removed from this excavation, and a rusty metal pipe leads into it. This feature appears to be some kind of old septic facility and is not karst-related.	
281-012	This is a spring/solution cavity that emerges from two small bedrock openings in the middle of a creek bed that are 0.2 m (0.7 ft) in diameter. When the site was recorded on 1 March 2010, water was flowing from both the spring orifices and from upstream in the creek. It is not known if the water coming from the spring is merely pirated from the stream flow nearby, or if it has a more distant source.	
281-013	This is a solutional sinkhole that was initially 0.4 m (1.3 ft) long and 0.3 m (1 ft) wide. It was developed in bedrock, and the bedrock belled out in shape toward the floor 0.15 m (0.5 ft) below the surface. It was filled with fine soils and leaf litter. Excavation was conducted to fully evaluate the feature on 11 August 2010 utilizing 9.75 person hours of effort. The feature was enlarged using a jackhammer to a post-excavation size of 0.75 m (2.5 ft) by 1 m (3.3 ft) with a depth of 0.75 m (2.5 ft), where a floor of bedrock and hard-packed clay was encountered. No mesocavernous voids extended from the feature.	

281-014	This is a closed depression that when initially assessed was 1.5 m (4.9 ft) long, 1 m (3.3 ft) wide, and 0.6 m (2 ft) deep. It was filled with leaf litter and modern soils. The troglophile meshweaver spider *Cicurina varians* was found in this feature. This feature was excavated on 10 August 2010 utilizing 0.8 person-hours of effort, resulting in the removal of 0.1 m^3 (3.5 ft^3) of material. A bedrock floor was reached at 0.7 m (2.3 ft) depth, with no mesocavernous voids leading off of the feature. The post-excavation dimensions of the feature were 1.5 m (4.9 ft) long, 1 m (3.3 ft) wide, and 0.7 m (2.3 ft) deep.	
281-015	This sinkhole is a depression is located on private property. It is 1.5 m (4.9 ft) long and 0.7 m (2.3 ft) wide, and was covered with trash when initially located on 2 March 2010. It had soil and leaf litter infill that was loose to a depth of 0.2 m (0.7 ft). The troglophilic meshweaver *Cicurina varians* was found in this feature. Excavation for further evaluation of karst invertebrate habitat was conducted on 10 August 2010 for one person-hour, resulting in the removal of 0.1 m^3 (3.5 ft^3) of material. A floor of hard-packed clay was reached at 0.25 m (0.8 ft) depth, with no mesocavernous voids extending from the feature. Post-excavation dimsinions of the feature were 1.6 m (5.2 ft) long by 0.8 m (2.6 ft) wide by 0.25 m (0.8 ft) deep.	

281-016	This enlarged fracture is located in the east road cut of US 281. When initially assessed on 2 March 2010. It had an opening 0.1 m (0.3 ft) in diameter, and it split into two routes with an estimated depth of over 1 m (3.3 ft). Airflow was detected, suggesting a continuation, therefore excavation of the feature was conducted for further evaluation. On 18 June 2010, 5 person hours of excavation effort was expended utilizing an electric chipping hammer. One cubic meter (35 ft^3) of material was removed. The feature was enlarged to a width of 1.5 m (4.9 ft), with several large slabs still blocking the way. These were removed with a jackhammer on 21 June 2010 in an effort that involved 6 person hours of labor and the removal of an additional 1 m^3 (35 ft^3) of material. Post-excavation dimensions of the feature were 0.7 m (2.3 ft) long by 1.5 m (4.9 ft) wide by 1 m (3.3 ft) deep. Bedrock was reached, with no signs of a drain or karst processes. This feature was likely formed by fracturing caused by excavation of the road cut during road building activities. Excavation showed that the road cut extended below the current level of bar ditch fill.	
281-017	This feature is situated in the eastern road cut of US 281. It is a solution cavity with two small entrances that are approximately 0.1 m (0.5 ft) in diameter. It drops vertically into the road cut for approximately 0.5 m (1.6 ft).	

281-018	This is a water utility site. The abundance of manmade features in this developed area is discussed in the body of this report.	
281-019	This feature is a water well near a business.	
281-020	When initially discovered, this feature was represented by nearly square shaped opening in the ground measuring 0.36 m (1.2 ft) by 0.33 m (1 ft) by 1.75 m (5.7 ft) deep. Photos of the interior of the feature revealed that is an abandoned hand-dug well or cistern.	

281-021	This solutional sinkhole measures 0.5 m (1.6 ft) by 0.4 m (1.3 ft) across and was 0.8 m (2.6 ft) deep. It was infilled with coarse rocks and organic sediment.	
281-022	This feature is a water well near a business.	
281-023	This feature is a water well behind a business.	
281-024	This non-karst closed depression measures 1 m (3.3 ft) long and 0.7 m (2.3 ft) wide and 0.3 m (1 ft) deep. It was filled with leaf litter, organic sediment, and trash. Two large rocks were removed from it during excavation on 13 August 2010. It was determined that this feature was formed by roots lifting rocks, and it is not karstic. Post-excavation dimensions of this feature were unchanged.	

<table>
<tr>
<td>281-025</td>
<td>(Taco Truck Tunnel) This is a cluster of closely spaced karst features, one of which is a cave. This cave is in a depression that measures 3 by 4 m across. One meter to the east of the cave is a solution hole that is 0.4 m (1.3 ft) in diameter. Three meters (10 ft) southeast of the cave is a solutionally-enlarged fracture that measures 0.76 by 0.91 m (2.3 by 2.5 ft), with a bearing of 137 degrees. Four meters (13 ft) to the southeast is a pair of fractures that form a cross 0.78 m (31 in) in diameter. These fractures have bearings of 77 and 167 degrees. The cave feature was recommended for excavation for further evaluation. Excavation took place on 13, 17, 19, 26, 27 August and 15-16 September 2010. Total excavation effort expended was 113 person hours, and 9.5 m^3 (335 ft^3)of soil and rocks was removed. The entrance to this cave is surrounded by sloping bedrock measuring 1.8 by 1.2 m (5.9 by 3.9 ft) across. It drops 1.3 m (4.3 ft) to a ledge, followed by a 2.3 m (7.5 ft) climb-down to a dirt floor. A crawlway extends to the northwest for 1.5 m (4.9 ft), where the cave ends in a small dome. The post excavation dimensions of the cave were 5 m (16.4 ft) long by 3.5 m (11.5 ft) wide by 5 m (16.5 ft) deep. A lithic arrow point was found during soil excavations at this cave. The cave was named for a nearby dining establishment.</td>
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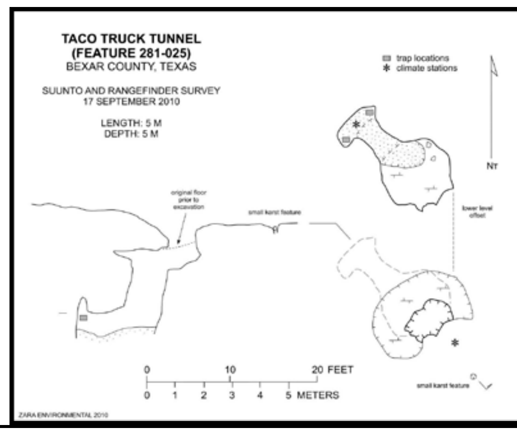

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281-026	This solutional sinkhole was initially 1.3 m (4.3 ft) long and 1.2 m (3.9 ft) wide. It was 0.6 m (2 ft) deep and contained leaf litter and clean-washed rocks. The feature is formed along a fracture trending at 45 degrees. Excavation for further evaluation was conducted with hand tools on 19 August, and with a jackhammer on 10 September 2010. A total of 5 person hours of effort was expended, resulting in the removal of 1.3 m^3 (46 ft^3) of material. A bedrock floor was reached at a depth of 0.5 m (1.6 ft). Lateral excavation along a bedding plane for 0.5 m (1.6 ft) revealed nothing but hard-packed clay. Post-excavation dimensions of the feature were 1.3 m (4.3 ft) long and 1.25 m (4.1 ft) wide and 0.6 m (2 ft) deep.	
281-027	This feature is a water well.	
281-028	This feature is a water well.	

281-029	This sinkhole is a depression that was initially 0.56 m (1.8 ft) long and 0.48 m (1.6 ft) wide. It had a noticeable drain, and contained fine infill comprised of leaf litter and organic sediment. Excavation conducted on 2 August 2010 to fully evaluate this feature resulted in the removal of a large rock and decaying sticks. A bottom of hard red clay was reached and no continuing drain could be seen. However, flood debris seen piled on top of the feature after a heavy rain indicates that it may have a high rate of infiltration. Post-excavation dimensions of this feature were 1 m (3.3 ft) in diameter with a depth of 0.3 m (1 ft).	
281-030	This depression of undetermined origin contains old stumps, concrete, and rocks. When discovered, it measured 0.5 by 0.25 m (1.6 by 0.8 ft), and was 0.2 m (0.7 ft) deep. Excavation was conducted on 2 August 2010 in order to determine if it was karstic, and 1 m^3 (35 ft^3)of material was removed utilizing hand tools. This material consisted of chunks of concrete and juniper stumps. The feature was excavated to a depth of 0.75 m (2.5 ft), about 0.2 m (0.7 ft) past the black soil layer into red and white clay. No drains were found. Post-excavation dimensions of this feature were 1.25 m (4.1 ft) in diameter and 0.75 m (2.5 ft) deep. Due to previous anthropogenic activity on the feature, the origin is unclear.	

281-031	This sinkhole is composed of a pair of depressions that lies within an area 3.5 m (11.5 ft) in length by 1 m (3.3 ft) wide. They had coarse infill and organic sediment and may be the result of tree removal. It was recommended for excavation in order to determine if it was karstic. Excavation took place on 2 August 2010, and resulted in the removal of 0.4 m^3 (14 ft^3) of soil from the two depressions. They were dug to depths of 0.3 and 0.4 m (1 and 1.3 ft) to hard packed bottoms with no drains. Post-excavation dimensions of the features were 1 m (3.3 ft) by 0.5 m (1.6 ft) by 0.4 m (1.3 ft) and 0.5 m (1.6 ft) in diameter by 0.3 m (1 ft) deep.	
281-032	This sinkhole is 1 m (3.3 ft) long and 0.8 m (2.6 m) wide. It receives recharge from an area measuring 3 by 5 m (9.8 by 16.4 ft). It contained infill of leaf litter and clean-washed rocks. An opossum was observed in this feature. Excavation was conducted on 2 August 2010 for a full evaluation. Black soil and rocks were removed from the floor, reaching a hard-packed bottom with no drains at a depth of 0.9 m (2.9 ft). Post-excavation dimensions of the feature were 1 m (3.3 ft) in diameter and 0.9 m (2.9 ft) deep.	
281-033	This feature is a well.	

281-034	This feature is a well.	
281-035	This is a cluster of three non-karst closed depressions on private property at the northwest corner of Overlook Parkway and US 281. When initially assessed, their origin was not clear. Excavation took place on 19 August 2010 for 1 person-hour, resulting in the removal of 0.25 m^3 (8.8 ft^3) of material. Excavation reached hard-packed soil at a depth of 0.35 m (1.1 ft). This feature is likely the result of tree-clearing, not karst processes. Post-excavation dimensions of the largest feature were 1.5 m (4.9 ft) in diameter and 0.35 m (1.1 ft) deep.	
281-036	This non-karst closed depression is located on private property at the northwest corner of Overlook Parkway and US 281. When initially examined, it had a diameter of 1.2 m (3.9 ft) and a depth of 0.5 m (1.6 ft). It was recommended for excavation for a better assessment, which took place on 19 August 2010. This excavation utilized 1.4 person-hours of effort, and resulted in the removal of 0.1 m^3 of material. A bedrock floor was reached with no mesocavernous voids extending from the feature. Post-excavation dimensions of the feature were 1.5 m (4.9 ft) in diameter and 0.75 m (2.5 ft) deep. This feature is likely the result of tree-clearing, not karst processes.	

<table>
<tr>
<td>281-037</td>
<td>(Painful Crawl) This cave is formed in an enlarged bedding plane in a road cut associated with a parking lot outside of the ROW. It was partially filled with concrete, but a low passage could be seen extending into the road cut. Excavation was conducted on 15-16 September 2010 to make a full assessment. This resulted in 2 m^3 (106 ft^3) of rocks being removed from the cave using 20 person hours of effort with hand and power tools. This cave is developed in a low, wide bedding plane, and is just tall enough for human entry. The bedrock and flowstone floor is rough, giving rise to the name Painful Crawl. Excavation concentrated on removing bits of rock from the floor and ceiling in order to be able to enter the passage, but did not change the existing footprint of the cave. Excavation continued 10 m (32.8 ft) until dark zone habitat was reached. The entrance to Painful Crawl is at the bottom of a sloping road cut that is 3.5 m tall. It is 1.4 m (4.6 ft) wide and 0.4 m (1.3 ft) tall. After 3 m (9.8 ft), the passage takes a turn to the east, with small bedding plane openings also extending off to the south and west at this turn. After another 4 m (13 ft), a junction is reached. A dig lead to the north appears that it would connect back to the road cut if excavated. A dig lead also extends to the east. The main passage continues to the south for 3 m (9.8 ft) before it gets too low for human entry. Post-excavation dimensions of the cave were 10 m (32.8 ft) long by 5m (16.4 ft) wide by 0.7 m (2.3 ft) deep.</td>
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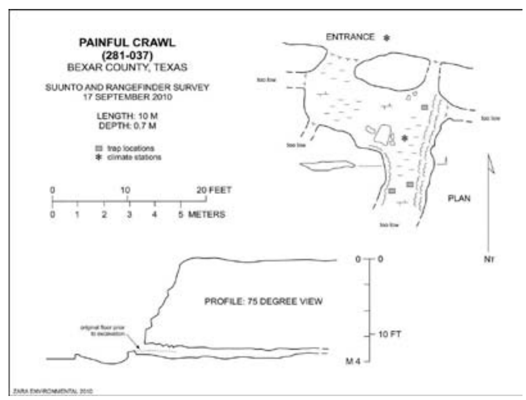

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281-038	This solutional sinkhole is 2.3 m (7.5 ft) long, 1 m (3.3 ft) wide, and 0.4 m (1.3 ft) deep. It consists of two holes draining under a bedrock shelf, with infill of leaf litter and organic sediment that is loose to a depth of 0.2 m (0.7 ft). Excavation was recommended to make a full assessment, but right of entry for excavation purposes was not granted.	
281-039	This non-karst closed depression is located on private property on the west side of US 281. When initially located it was a depression 0.25 m (0.8 ft) in diameter and 0.13 m (0.4 ft) deep, with coarse and fine infill of rocks and organic sediment. Excavation was conducted on 10 September 2010 to make a full assessment. This utilized 0.6 person-hours of effort and removed 0.1 m^3 (3.5 ft^3) of material. Post excavation dimensions of this feature were 1.5 m (4.9 ft) long by 0.75 m (2.5 ft) wide by 0.5 m (1.6 ft) deep. This feature is located in a landfill deposit, and is a result of poor consolidation.	
281-040	This non-karst closed depression is located on private property on the west side of US 281. When initially located, it was 1.3 m (4.3 ft) in diameter and 0.3 m (1 ft) deep. It had infill of leaf litter and organic sediment. Excavation was conducted on 10 September 2010, utilizing 1 person-hour of effort and removing 0.2 m^3 (7 ft^3) of rocks and soil to a bedrock floor. Post-excavation dimensions of this feature were 1.4 m (4.6 ft) in diameter and 0.6 m (2 ft) deep. This feature is erosional in origin, likely the result of bedding plane slumping on a hillside slope.	

281-041	This solutionally-enlarged fracture is located on private property on the west side of US 281. Prior to excavation, it measured 0.8 m (2.6 ft) in length by 0.1 m (0.3 ft) in width, and was 0.3 m deep. It contained fine, black organic sediment of modern origin. Evaluation via excavation was conducted with a jackhammer on 10 September 2010 utilizing 2 person-hours of effort and removing 0.3 m^3 (10.6 ft^3) of material. The excavation reached a bedrock floor at a depth of 0.6 m (2 ft), with no mesocavernous voids extending off of it. Post-excavation dimensions of the feature were 1.25 m (4.1 ft) long by 0.75 m (2.5 ft) wide by 0.6 m (2 ft) deep.	
281-042	This non-karst closed depression is located on private property on the west side of US 281. When initially assessed, it consisted of two depressions within an area measuring 1 by 2 m (3.3 by 6.6 ft). It had infill of leaf litter and organic sediment that was loose to a depth of 15 cm (0.5 ft). Excavation was conducted on 10 September 2010. This effort utilized 1 person-hour of effort and removed 0.1 m^3 (3.5 ft^3) of material. Post-excavation dimensions of the largest feature were 0.75 m (2.5 ft) in diameter and 0.3 m (1 ft) deep. This feature is an old, filled animal burrow that goes under a slab of limestone and exits the other side.	
281-043	This non-karst closed depression was 2 m (6.6 ft) in diameter and 1 m (3.3 ft) deep when initially assessed. It had fine infill of leaf litter and organic sediment. Excavation was conducted on 3 August 2010; 1 m^3 (35 ft^3) of dirt and leaves was removed from the feature. Post-excavation dimensions of the feature were 2 m (6.6 ft) long by 2.5 m (8.2 ft) wide by 1 m (3.3 ft) deep. The floor was hard-packed red clay, with an animal burrow at the south end of the feature. Construction activities on this site later resulted in the area being graded over.	

281-044	When initially assessed, this solutional sinkhole was 2.5 m (8.2 ft) long, 1.25 m (4.1 ft) wide, and 1.2 m (3.9 ft) deep. It contained infill composed of leaf litter and organic sediment that was loose to a depth of 20 cm. It is recharged by sheet-wash from an area measuring 30 by 30 m (98 by 98 ft). Excavation in order to further evaluate the feature on 3 August 2010 removed 2.5 m^3 (88 ft^3) of loose soil and rocks, deepening the feature to 1.8 m (5.9 ft). Post-excavation dimensions of this feature were 2.5 m (8.2 ft) long, 1.25 m (4.1 ft) wide, and 1.8 m (5.9 ft) deep. At that point right of entry for excavation was revoked, preventing further excavation that would likely have led to a cave. The feature was backfilled.	

<table>
<tr>
<td>281-045</td>
<td>This cave is located in a drainage, and consists of two low enlarged bedding planes that cut back under the drainage. Flood waters cascading down over the top of these entrances has caused scour, piling up gravel and rocks just downstream. The westernmost of the two entrances extends in for 3 m (9.8 ft) to a bedrock terminus. The eastern entrance extends 4 m (13.1 ft) and also terminates in bedrock. Excavation was conducted on 4, 19, and 25 August to enlarge these bedding plane openings for biological evaluation. Using hand and power tools, 2 m^3 (71 ft^3) of material was removed with 25.5 person hours of effort. The cave was mapped during a subsequent visit. Post-excavation dimensions of this feature were 7 m (23 ft) long, 4 m (13.1 ft) wide and 0.7 m (2.3 ft) deep.</td>
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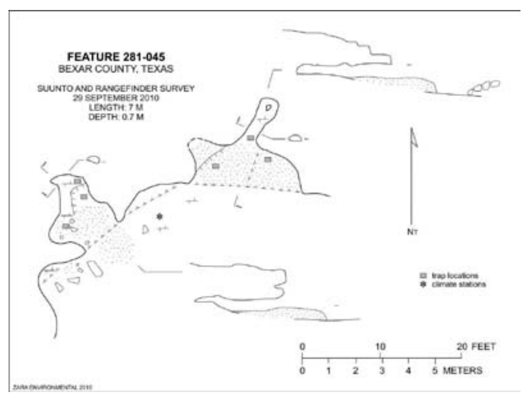
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<tr>
<td>281-046</td>
<td>When initially assessed, this non-karst closed depression was 0.3 m (1 ft) in diameter containing roots and water. It had infill of leaf litter and organic sediment. Excavation conducted on 4 August 2010 removed some soil, and revealed an animal burrow. Post-excavation dimensions of the feature were 1 m (3.3 ft) in diameter by 0.5 m (1.6 ft) deep.</td>
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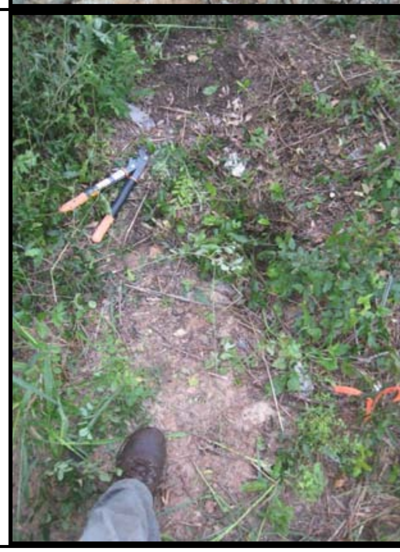
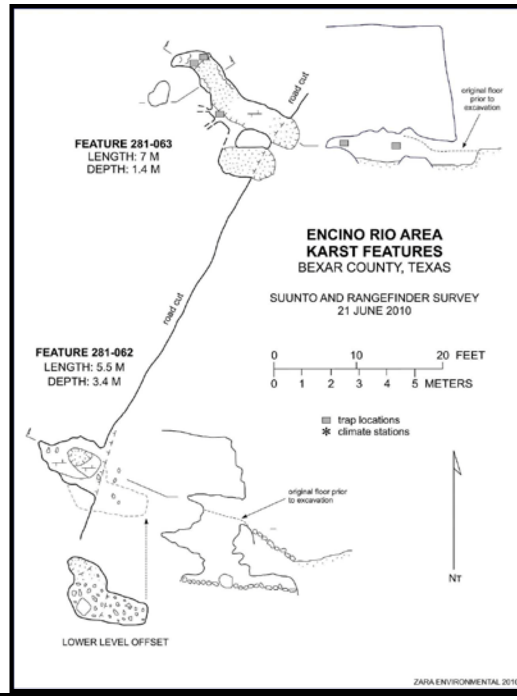
281-047	When initially assessed, this sinkhole was 1.5 m (4.9 ft) long, 1 m (3.3 ft) wide, and 0.4 m (1.3 ft) deep. It contained fine black sediment of modern soil and leaf litter. It was excavated on 3 August 2010 to a solid bedrock floor.	
281-048	This solutional sinkhole is 3 m (9.8 ft) long and 1 m (3.3 ft) wide and contained fine infill of black, modern soil and leaf litter. Airflow was detected in the feature on 12 March 2010. It was recommended for evaluation via excavation, but right of entry for excavation purposes was denied.	
281-049	This feature is a water well. It was viewed over a fence on a property with a no trespassing sign which did not grant right of entry. No photograph is available because there was not a clear view from the fence.	No photograph available.
281-050	This feature is a water well. No further information is available about this well.	No photograph available.

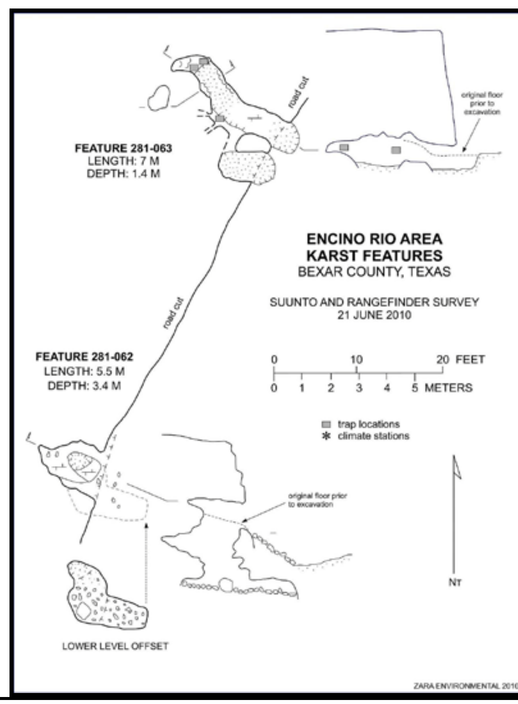
281-051	This is a set of enlarged cross-fractures located on private property. The feature was 2.5 m (8.2 ft) long, 0.2 m (0.7 ft) wide, and 0.3 m (1 ft) deep. The main fracture trends at approximately 90 degrees, with several minor fractures crossing at 45 degrees. It receives sheet-wash drainage from an area measuring 20 by 30 m (66 by 98 ft). It has infill of organic sediment and leaf litter that is loose to a depth of 0.3 m (1 ft). It was recommended for excavation, but right of entry for excavation purposes was not obtained.	
281-052	This non-karst closed depression is located on the west side of US 281 on private property. It is a 10 m-diameter (32.8 ft) depression with a depth of 1.5 m (4.9 ft) formed by the introduction of landfill material on its north side and not by karst processes.	
281-053	This non-karst closed depression is located on the west side of US 281 on private property. It is composed of three openings within an area that is 3 m (9.8 ft) long, 0.6 m (2 ft) wide, and 1 m (3.3 ft) deep. This feature is located in the same landfill deposit as feature 281-052. It was recommended for excavation, but when excavation commenced on 10 September 2010, it was immediately determined to be non-karstic. It is formed in a landfill deposit, and is a result of collapse or piping into loose fill.	

281-054	This solution cavity is at the base of a road cut on private property on the east side of US 281. This opening is 8 m (26.2 ft) wide, 0.3 m (1 ft) tall, and extends at least 0.6 m (2 ft) into the cut.	
281-055	This solution cavity is an enlarged bedding plane at the base of a construction site road cut on private property. It is 2 m (6.6 ft) wide, 1.7 m (5.6 ft) tall, and extends into the road cut for 1 m (3.3 ft). It is developed along a fracture bearing 90 degrees.	
281-056	This non-karst closed depression is located on the east side of 281, in the north flood plain of Mud Creek. When initially assessed, it was a depression in soil 1 m (3.3 ft) in diameter and 0.5 m (1.6 ft) deep. Evaluation via excavation was conducted at this feature on 20 May 2010 by two persons for 50 minutes. Approximately 0.05 m^3 (1.8 ft^3) of fill was removed from the feature to reveal an animal burrow. Post-excavation dimensions of this feature were 1 m (3.3 ft) in diameter by 0.75 m (2.5 ft) deep.	

281-057	This sinkhole consists of a depression that is 1.5 m (4.9 ft) in diameter and 0.4 m (1.3 ft) deep. It has a large rock on its south side, and is filled with fine-grained organic sediment and leaf litter that is loose to a depth of 0.3 m (1 ft). There is a small tree with some exposed roots growing from the feature. The feature receives sheetwash flow from an area measuring 25 by 30 m (82 by 98 ft). It was recommended for excavation to make a full evaluation, however right of entry was rescinded prior to the initiation of excavation activities.	
281-058	This potential sinkhole is a depression that is 3.5 m (11.5 ft) in diameter and 0.7 m (2.3 ft) deep. It is filled with soil and has two live oak trees growing out of it. It was recommended for excavation in order to determine its origin; however, right of entry was rescinded prior to the initiation of excavation activities.	
281-059	This non-karst closed depression is 5 m (16.4 ft) long, 3 m (9.8 ft) wide, 0.5 m (1.6 ft) deep, and is surrounded by a curbed parking lot. There are two oak trees within it. It was most likely formed by the area surrounding it being built up for the parking lot, with the area around the trees left unfilled so that the trees would not die.	

281-060	This solution cavity is an enlarged bedding plane opening in a road cut on the west side of US 281. It consists of three side by side openings within an area 2.25 m (7.4 ft) wide. They are 0.3 m (1 ft) tall and extend no more than 0.5 m (1.6 ft) into the road cut.	
281-061	This feature is an enlarged fracture developed along a trend of 90 degrees in a road cut on the west side of US 281. It is 0.4 m (1.3 ft) wide, 0.9 m (2.9 ft) tall, and extends into the road cut for 1.25 m (4.1 ft).	No photograph available.

281-062	When this cave in the road cut on the west side of US 281 was first discovered, it had a 1.9 m wide and 0.75 m high entrance, and extended 2 m (6.6 ft)into the road cut. Excavation was conducted on 3 June 2010 for a full evaluation, and 3 m^3 of material was removed. These rocks were lightly cemented together with calcite, with voids between them. The excavation trended back underneath the roadway with an unstable ceiling, and excavation efforts ceased about 5 m into the feature. Post-excavation dimensions of the cave were 5.4 m long (17.7 ft) by 1.5 m (4.9 ft) wide and 3.4 m (11.1 ft) deep.	 

281-063	This cave is in the road cut on the west side of US 281, south of Encino Rio. It has two entrances at the base of the road cut that were initially 0.5 m (1.6 ft) wide. The northern entrance could be seen to extend 2 m into the road cut and continued on. It contained infill of leaf litter and organic sediment. It was excavated on 3, 14, and 23 June 2010. These excavations resulted in the removal of 3 m^3 of material from the feature. The resulting cave is 7 m (23 ft) long, with a small connection between the two entrances that is not humanly passable. Each entrance is 1 m (3.3 ft) wide and both passages drop below the level of the roadway shoulder to a depth of 1.4 m (4.6 ft). The south entrance quickly rejoins the main passage in the north section. The cave ends in a flowstone wall.	  

281-064	This is a non-karst closed depression at the base of the road cut on the west side of US 281. When initially assessed it was 2 m (6.5 ft) in diameter and 0.3 m (1 ft) deep. It had infill of leaf litter and fine-grained organic sediment. It receives sheetwash from a drainage area of 600 m^2 (6,458 ft^2) from the bar ditch. It was excavated on 14 June 2010 for further evaluation; 0.05 m^3 (1.8 ft^3) of material was removed with 2 person hours of labor. Post-excavation dimensions of the feature were 2 m (6.5 ft) in diameter and 1.25 m (4.1 ft) deep. Excavation reached a bedrock bottom with an apparent drain hole. However, this hole is actually a drill hole from the original road cut construction, not part of a natural karst feature.	
281-065	This is a solutionally enlarged fracture in the road cut on the west side of US 281 that had an opening 0.5 m (1.6 ft) wide and 1 m (3.3 ft) high. It dropped downward at least 0.5 m (1.6 ft). It was excavated on 17, 21, and 23 June 2010 for 17 person hours, removing 1.25 m^3 (44 ft^3) of hard rock with jackhammers. After excavating to a depth of 1 m (3.3 ft), no voids could be seen extending from the feature. Post-excavation dimensions of the feature were 1 m (3.3 ft) in length by 1 m (3.3 ft) in width by 1 m (3.3 ft) in depth.	
281-066	This solution cavity is located in the road cut on the west side of US 281. It has a trend of 90 degrees that is 0.5 m (1.6 ft) wide, 0.25 m (0.8 ft) tall, and it extends into the road cut for 1.25 m (4.1 ft).	

281-067	This feature appears to be a collapse sinkhole. It is 1 m (3.3 ft) in diameter and 0.3 m (1 ft) deep, with infill composed of organic sediment, leaf litter, and rocks. It was recommended for evaluation via excavation, but right of entry for that purpose was denied.	
281-068	This feature is a water well.	
281-069	This solution cavity is an enlarged bedding plane located in the road cut on the east side of US 281. It is 1.5 m (4.9 ft) wide, 0.5 m (1.6 ft) tall, and extends into the road cut for 1.5 m (4.9 ft). It has coarse grained infill consisting of rocks.	

<table>
<tr>
<td>281-070</td>
<td>(Stafford Cave) This cave is located in the east road cut of US 281. It is an enlarged bedding plane that had an entrance 0.4 m (1.3 ft) m in diameter, and it could be seen to extend 1.5 m (4.9 ft) into the road cut with a small opening continuing on. Slight airflow was detected. It was excavated on 16-17 June 2010 for full evaluation. Fourteen person-hours of effort were utilized to remove rocks in order to make the crawlway passable. The cave can be entered for 9 m (29.5 ft) before it becomes too low to pass. The post-excavation width was 2 m (6.6 ft) and the depth was 1 m (3.3 ft). The cave was named for the brand of an article of clothing found in the entrance.</td>
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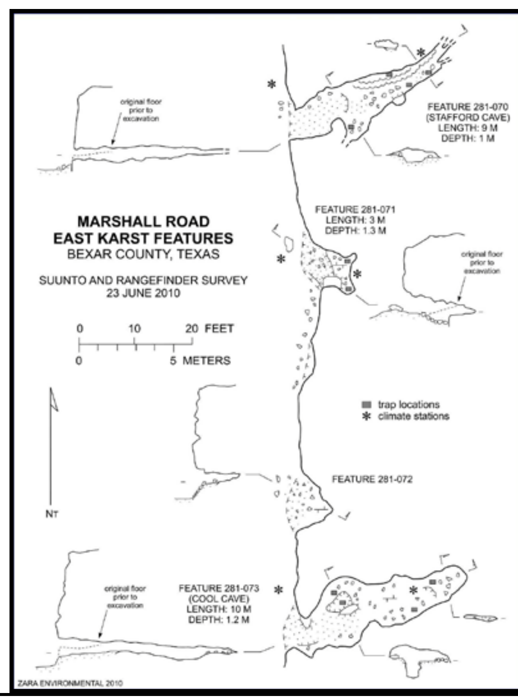

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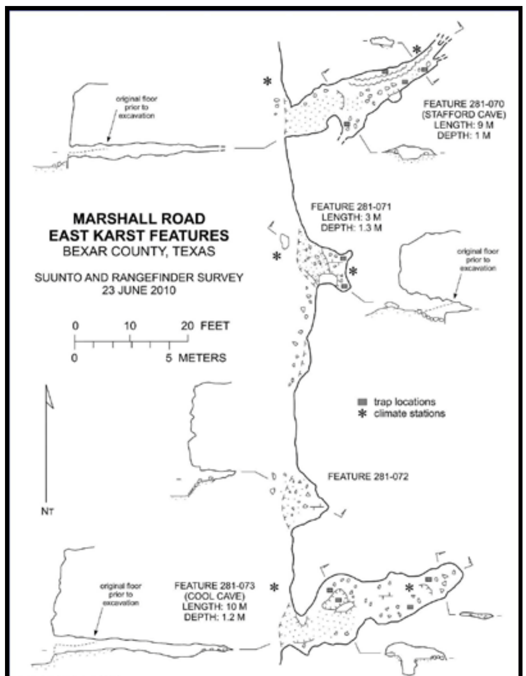
281-071	This solution cavity is located in the east road cut of US 281. It is an enlarged bedding plane with an entrance that is 2 m (6.6 ft) wide and 1 m (3.3 ft) high. It extended for 3 m (9.8 ft) into the road cut, with a small hole continuing on. Previous excavation has occurred here, as evidenced by a tailings pile just outside of the entrance. It was excavated on 16 June 2010for a full evaluation. About 1m^3 (35 ft^3) of rock was removed from the back of the feature, which was a bedding plane shelf with small openings continuing on. The post-excavation dimension were 3 m (9.8 ft) long by 2 m (6.6 ft) wide by 1.3 m (4.3 ft) deep. One troglobite (*Brackenridgia* sp.) was encountered during excavation.	
281-072	This solution cavity is an enlarged bedding plane opening that is 2.5 m (8.2 ft) wide, 0.4 m (1.3 ft) tall, and extends 1.5 m (4.9 ft) into the road cut. Tiny mesocavernous voids extend off of it in the same bedding plane as surrounding caves and features.	

281-073

(Cool Cave) This cave is developed in an enlarged bedding plane in the east road cut of US 281. When initially assessed, its entrance was 2 m (6.6 ft) wide and 0.5 m (1.6 ft) high. It extended at least 3 m (9.8 ft) into the road cut, with mesocavernous voids continuing on. It was excavated on 15-16 June 2010 for a full evaluation. Three m^3 (106 ft^3) of material was removed utilizing 20 person-hours of labor with hand and power tools. This resulted in enlargement of the entrance to 1m (3.3 ft) in height, and enabled access to the full 10 m (32.8 ft) length of the cave. It was named for the cool temperature inside relative to the outside summer heat. The cave begins as a dirt-floored crawl, and widens out to 3.5 m (11.5 ft) across. At this point there is a shallow pit on the north side of the passage with a damp bedrock floor. The back portion of the cave gets very low. The post-excavation dimensions of this feature were 10 m (32.8 ft) long by 1 m (3.3 ft) wide by 1.2 m (3.9 ft) deep.

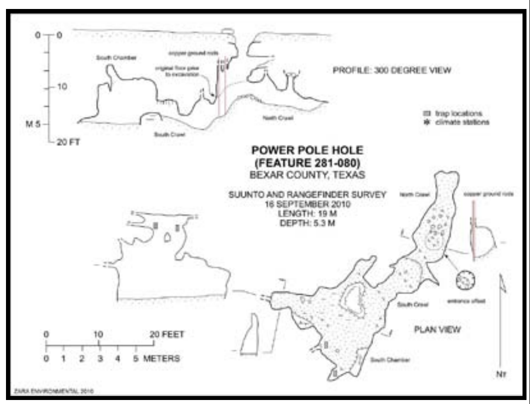


281-074	This solution cavity is an enlarged bedding plane in the road cut on the east side of US 281. It is 1 m (3.3 ft) wide, 0.3 m (1 ft) tall, and extends into the road cut for 1 m (3.3 ft).	
281-075	This solution cavity is an enlarged bedding plane developed in the east road cut of US 281. When initially assessed it was 1 m (3.3 ft) wide, 0.4 m (1.3 ft) tall, and extended into the road cut for 1.5 m (4.9 ft). It contained fine-grained organic sediment, rocks, and leaf litter. This feature receives channelized flow from the highway bar ditch. The troglophile meshweaver spider *Cicurina varians* was found in this feature. Excavation was conducted on 15 June 2010 to make a full assessment. Eight person hours of effort utilizing hand tools resulted in the removal of 1 m^3 (35 ft^3) of material. This resulted in the enlargement of the entrance to 1.5 m (4.9 ft) in diameter, and the floor was lowered to 1 m (3.3 ft) below the elevation of the bar ditch for a total depth of 2 m (6.6 ft). The floor was composed of clay that extended up the walls to meet the bedrock ceiling, with no voids visible.	
281-076	This solution cavity is an enlarged bedding plane in the east road cut of US 281. The entrance to the feature is 0.5 m (1.6 ft) wide and 0.3 m (1 ft) tall. It extends into the road cut for 1 m (3.3 ft). It contains smooth bedrock walls with no infill material.	

281-077	This solution cavity is an enlarged fracture with a trend of 150 degrees. It is situated in the east road cut of US 281. The entrance is 0.25 m (0.8 ft) wide, 0.25 m (0.8 ft) tall, and it extends into the road cut for 0.4 m (1.3 ft). It contains minor amounts of rock infill, and flowstone covering some surfaces. Gastropod shells were observed in this feature.	
281-078	This solution cavity is located in the east road cut of US 281. It is an enlarged bedding plane with an entrance that is 0.4 m (1.3 ft) wide and 0.2 m (0.7 ft) high. It extends at least 1.5 m (4.9 ft) into the road cut with a continuing void, and has slight airflow. It was excavated on 21 June 2010. Utilizing 6 person-hours of labor, 1 m^3 (35 ft^3) of material was removed; no continuing voids were seen. Post-excavation dimensions of the feature were 1.5 m (4.9 ft) long by 1 m (3.3 ft) wide by 0.5 m (1.6 ft) deep.	
281-079	This feature is located on private property on the east side of US 281. The entrance is 0.4 m (1.3 ft) wide, 0.3 m (1 ft) tall, and it extends in for at least 0.5 m (1.6 ft). It appears to be an epikarstic void that was enlarged by animal burrowing.	

281-080

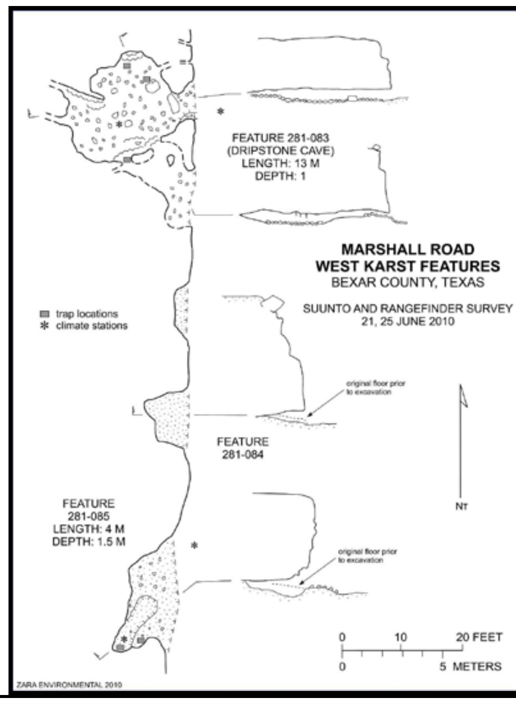
(Power Pole Hole) This cave is located on the west side of US 281, to the south of Sonterra Boulevard. It is just inside the ROW, about 8 m (26.2 m) from the edge of pavement of the US 281 feeder road. This is a cave that was apparently intersected by power pole drilling installation operations sometime in the past. Although this feature was partially open when initially assessed, excavation was needed to remove fill material that had been dumped in. A large quantity of recycled asphalt had been dumped into the cave in an apparent effort to plug the cave. Excavations were conducted on 20 May, 11, 12, 17, and 29 June, 19, 20, and 26 August, and 10 and 17 September 2010. A total of 8.16 m^3 (288 ft^3) of material was removed from the feature using 97.8 person-hours of effort. The entrance to Power Pole Hole is 0.8 m (2.6 ft) in diameter and was covered with a limestone slab when initially encountered. When initially assessed, the cave consisted of a 3 m (9.8 ft) climb-down to a plugged floor. The northern crawlway went for 3 m (9.8 ft) to a terminus. The southern crawlway went down the slope past the ground rods, and then sloped upward in a low section that opened up into a spacious chamber. This chamber is about 7 m (23 ft) across and up to 4.5 m (14.8 ft) in height. Flowstone and stalactites cover parts of the ceiling, walls, and floor. Most of the floor consists of silt. Mesocavernous voids extend off of the western portion of the room at different points of the walls and ceiling. Post-excavation dimensions of this feature were 13 m (42.7 ft) long by 5 m (16.4 ft) wide) by 1 m (3.3 ft) deep. This cave receives a considerable amount of moisture from various sources. Drainage is channeled into it by landscaping modifications related to an adjacent hotel. The hotel filtration pond drains into it. Sprinklers installed to water the grass on the ROW also drain to the cave.



281-081	This solution cavity is located in the west road cut of US 281. It is an enlarged bedding plane with an entrance that is 1.5 m (4.9 ft) wide and 0.3 m (1 ft) high. It can be seen to extend into the road cut for at least 1.25 m (4.1 ft). This passage is initially 0.4 m (1.3 ft) wide, and splits into two branches which become smaller. The right hand branch contains some concrete of unknown origin. This concrete may have flowed out of this branch when some feature was plugged above. Visible surfaces are covered with calcite.	
281-082	This solution cavity is located in the west road cut of US 281. It is an enlarged bedding plane with an entrance that is 3 m (9.8 ft) wide and 0.5 m (1.6ft) high. It extends into the road cut for 1 m (3.3 ft), and has no voids extending off of it. It contains no infill material and exhibits no evidence of moisture or speleothems.	

281-083

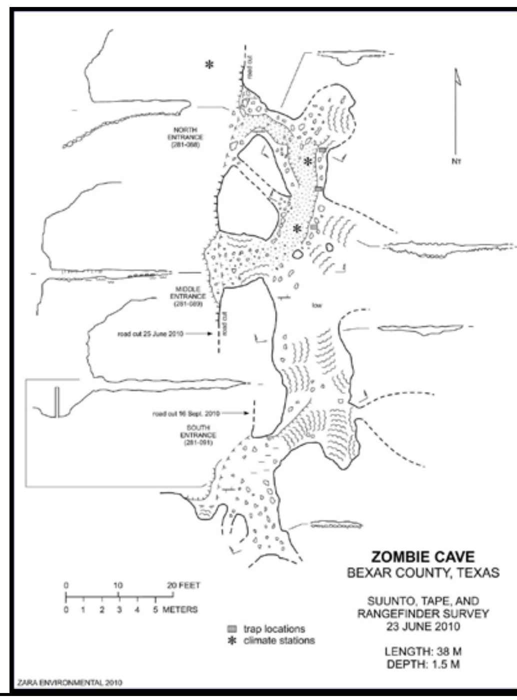
(Dripstone Cave) This cave is located in the western road cut of US 281, to the south Marshall Road. It is formed in an enlarged bedding plane. Two entrances 3 m (9.8 ft) apart join up as a wide, low bedding plane void that was likely formed under phreatic conditions. The cave is 13 m (42.7 ft) long by 5 m (16.4 ft) wide by 1 m (3.3 ft) deep. This cave is located at the very base of the road cut and receives channelized recharge from the bar ditch. The entrance had been previously excavated. The walls and ceiling of this cave are mostly covered in calcite, which gave rise to the name Dripstone Cave. The floor is covered in loose, calcite-encrusted rocks. There is little organic debris, apart from some mammal scat. Several small voids extend off of the back of the cave.



281-084	This solution cavity is located on the west side road cut of US 281, to the south of Marshall Road. It is formed in an enlarged bedding plane. When initially assessed the entrance was 1.3 m (4.3 ft) wide and 0.35 m (1.1 ft) high, and it extended over 1.5 m (4.9 ft) into the road cut. The passage made an 80 degree turn to the right beyond which it could not be examined. It was evaluated via excavation on 18 June 2010. Using hand tools, 1.25 m^3 (44 ft^3) of material was removed with 9.5 person hours of effort. This enlarged the feature to 3 m (9.8 ft) in width, 1.25 m (4.1 ft) in height, and extending just over 2 m (6.6 ft) into the road cut. No continuing voids existed.	
281-085	This solution cavity is located in the western road cut of US 281, to the south Marshall Road. It is formed in an enlarged bedding plane at the base of the road cut, and it takes channelized drainage from the bar ditch. The entrance is 4 m (13.1 ft) wide and 2 m (6.6 ft) tall. When initially assessed it quickly became too low to enter, but extended at least 3 m (9.8 ft) into the road cut and was considered to be potentially humanly-enterable. Evaluation via excavation was conducted on 18 June 2010 for 6 person hours, removing 0.75 m^3 (26.5 ft^3) of material from the feature. The floor was lowered, enabling the back of the feature to be examined. Post-excavation dimensions of the feature were 4 m (13.1 ft) in width and 2.5 m (8.2 ft) in height and extended 3 m (9.8 ft) into the road cut. No voids continued on.	

281-086	This solution cavity is located in the western road cut of US 281, to the south Marshall Road. It is formed in an enlarged bedding plane. The entrance is 2 m (6.6 ft) wide and 0.45 m (1.5 ft) high. It extends 1 m (3.3 ft) into the road cut, at which point a small void that is not humanly-enterable continues for an unknown distance. It is formed at the base of the road cut, taking channelized drainage from the bar ditch. Previous excavation has occurred here, as evidenced by a tailings pile just outside of the entrance.	
281-087	This solution cavity is located in the western side road cut of US 281, to the south Marshall Road. It is formed in an enlarged bedding plane. The entrance is 3 m (9.8 ft) wide and 1.5 m (4.9 ft) high. It extends 1.5 m (4.9 ft) into the road cut. Some of the surfaces are covered in calcite. There are no mesocavernous voids extending from the feature.	

<table>
<tr>
<td>281-088</td>
<td>(Zombie Cave) This feature was revealed by roadway widening construction in June 2010. The entrance was 3 m (9.8 ft) wide, 0.5 m (1.6 ft) tall, and it could be seen to extend into the road cut for at least 4 m (13.1 ft). It was excavated on 23 and 26 August for a full evaluation. Excavation removed rocks from the floor to enable access to the interior of the cave. Features 281-089 and 281-091, which are adjacent to the south, were found to connect to it, giving this cave three entrances. All three entrances open into the same enlarged bedding plane, which it shares with other nearby caves in the road cuts south of Marshall Road. Noticeable airflow circulates through this cave, probably between these three entrances rather than from other sources. Maximum human penetration in Zombie Cave from the road cut to date is about 6 m (19.7 ft), but the enlarged bedding plane opening can be seen to continue on in a number of places which could be enlarged with more excavation effort. However, excavations completed to date were sufficient to complete evaluations for this assessment and for the karst invertebrate habitat assessment. Post-excavation dimensions of the cave are 38 m (124.7 ft in length with an average width of 5 m (16.4 ft) and a depth of 1.5 m (4.9 ft). The cave was named for the fact that it suddenly appeared from out of the earth.</td>
<td>

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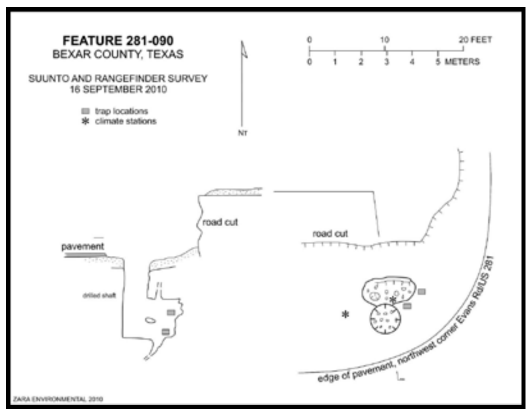
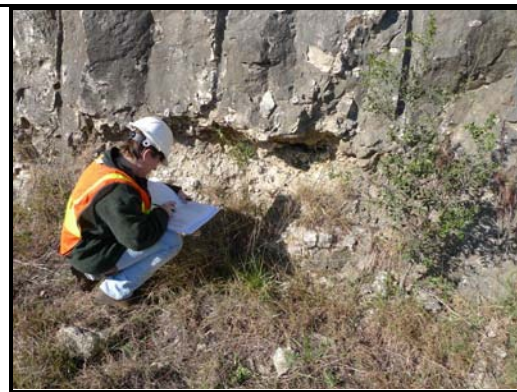
281-089	**(Zombie Cave)** This karst feature is located in the road cut just south of Zombie Cave, and upon excavation and investigation was found to connect to it. See the description of 281-088 for more information.	 See map at 281-088.

281-090	This solution cavity was encountered on August 2010 when a construction team working on the installation of a traffic signal at the intersection of Evans Road and 281 encountered a it while drilling a 1 m (3.3 ft) diameter foundation. Excavations were conducted on 25 and 26 August 2010 to remove drilling rubble in order to assess the void for karst invertebrate habitat. The drilled shaft was 3 m (9.8 ft) deep, with the void extending off of the north wall. The opening into the void extended from the floor of the shaft at -3 m (-9.8 ft) to a point 1.6 m (5.2 ft) above that. The total vertical extent of the void was 3 m (9.8 ft), with tiny voids extending off of the top and bottom of it. Post-excavation dimensions of the feature were 2 m (6.6 ft) long by 2.5 m (8.2 ft) wide and 3m (9.8 ft) deep, thus it was classified as a cave for recharge capacity. Most of the surfaces within the void were encrusted with calcite, including the floor drain which effectively plugged it.	  

281-091	**(Zombie Cave)** This is another feature located in the road cut south of Zombie Cave. This feature was exposed during road widening activities in August 2010. Excavation conducted at that time determined its connection to Zombie Cave. See the description of 281-088 for more information.	 See map at 281-088.
281-092	This feature is a fault exposed in the road cut on the west side of US 281. It has a strike of 53° and a dip of 50° with 1 m (3 ft) of displacement.	
281-093	This feature is a fault exposed in the road cut on the west side of US 281. It has a strike of 55° and a dip of 83° NW.	
281-094	This non-karst closed depression is 4 m (13.1 ft) long, 1.5 m (4.9 ft) wide, and 0.3 m (1 ft) deep. It has a hard-packed clay floor, with no drains. It is likely the result of land clearing operations.	

281-095	This solution cavity is located in the eastern road cut of US 281. When initially assessed, it was 1 m (3.3 ft) wide, 1.3 m (4.3 ft) tall, and it extended into the road cut for 0.5 m (1.6 ft). It contained some gravel infill that may be associated with construction excavation activities. The walls were partially covered with calcite. It is developed along a fracture with a trend of approximately 133 degrees. It was excavated on 1 October 2010. This effort removed 1 m^3 (35 ft^3) of material utilizing 6 person hours of labor. The feature was enlarged along the fracture to yield post-excavation dimensions of 1 m (3.3 ft) wide by 2 m (6.6 ft) tall, and it extended 1 m (3.3 ft) into the road cut. The fracture narrowed nearly to closure, with no airflow.	
281-096	This enlarged fracture is situated in the eastern road cut of US 281. It is 1 m (3.3 ft) wide, 1.2 m (3.9 ft) tall, and extends into the road cut for 1.5 m (4.9 ft). It contains some gravel infill that may be associated with construction excavation activities.	
281-097	This non-karst closed depression measures 10 by 25 m (32.8 by 82 ft), and is 4 m (13.1 ft) deep. It is an old quarry pit that has bedrock walls on three sides. The east side is composed of fill that made this a closed depression. It was most likely originally open on the east side for material removal.	No photograph available.

281-098	This solution cavity is an enlarged bedding plane on a creek bank. The entrance is 0.75 m (2.5 ft) wide, 0.3 m (1 ft) tall, and it extends into the creek bank for 1.6 m (5.2 ft). A fracture is present in the feature that has a trend of approximately 150 degrees. It has a coarse-grained infill of rocks. The roof of the feature is only about 0.5 m (4.9 ft) thick, and is in the process of being eroded away due to proximity to the creek. This feature is a result of that process.	
281-099	This closed depression is probably not karstic and was viewed from the ROW through a fence, but access was denied to the private property where it is located, barring further evaluation. It is 1 m (3.3 ft) long, 0.8 m (2.6 ft) wide, and 0.2 m (0.7 ft) deep. It appeared to have infill of leaf litter and organic sediment. It may be surface disturbance associated with fence building.	
281-100	This feature is a water well near some businesses. The well could not be fully assessed because it is contained in a shed to which access was not obtained.	
281-101	This feature is a water well located on private property to which access was not obtained. Well was viewed through the fence from the ROW.	

281-102	This solution cavity is an enlarged bedding plane located in the west road cut of US 281. The entrance to it is 0.3 m (1 ft) in diameter, and it extends into the road cut for 0.3 m (1 ft). It has a coarse-grained infill of loose rocks.	
281-103	This solution cavity is located on private property on the west side of US 281. The entrance is 0.25 m (0.8 ft) wide, 0.2 m (0.7 ft) long, and when initially assessed it dropped 0.4 m (1.3 ft) to a floor composed of organic debris and soil that was loose to a depth of loose. Preliminary excavation lowered the floor 0.1 m (0.15 ft), but more excavation would have required removal of some of the bedrock walls. This was recommended to assess karst invertebrate habitat, but right of entry for that purpose was denied.	
281-104	This consists of two solution cavities in the east US 281 road cut, one of which is associated with a fracture. The north cavity is 0.8 m (2.6 ft) wide, 1.2 m (3.9 ft) tall, and extends into the road cut for 0.2 m (0.7 ft). The south cavity is 0.4 m (1.3 ft) wide, 1.3 m (4.3 ft) tall, and extends into the road cut for 0.7 m (2.3 ft). These contain coarse infill of rocks that is likely a consequence of road cut excavation.	No photo available.
281-105	This solution cavity is an enlarged fracture located in the west road cut of US 281. The entrance that is 3 m (9.8 ft) wide, 0.7 m (2.3 ft) tall, and it extends 1 m (3.3 ft) into the road cut. It contains smooth bedrock walls.	

281-106	This is a zone of solutionally enlarged fractures in the streambed of West Elm Creek with a bearing of 106°.	
281-107	This appears to be a solution cavity encountered during down-cutting of bedrock grade in a private property construction area. It is 1.5 m (4.9 ft) long, 1.3 m (4.3 ft) wide, and is 0.25 m (0.8 ft) deep. It has an infill of rocks and fine white silt (powdered bedrock) that appears to be the result of construction activitities. It was recommended for excavation to make a full evaluation, but right of entry for excavation purposes was not obtained.	
281-108	This non-karst closed depression is located on the east US 281 ROW in an area that was partially cleared of trees in the past. It is 0.8 m (2.6 ft) long, 0.6 m (2 ft) wide, and is 0.3 m (1 ft) deep. When initially assessed, it had an infill of fine-grained organic sediment. It was excavated on 16 November 2010, which resulted in the removal of 5 cm (0.2 ft) of soil to reveal a bedrock floor. This feature is probably a result of tree removal.	

281-109	This possible solution cavity is located on private property on the west side of US 281. It consists of two 10 by 20 cm (0.3 by 0.6 ft) holes that are 1 m (3.3 ft) apart, one of them open and one plugged. The eastern hole drops for 0.2 m (0.7 ft) to dirt fill. This feature was recommended for excavation. No determination could be made about this feature due to lack of ROE for excavation purposes. This may be an animal burrow under a slab of rock that has been mostly filled with soil by site grading.	

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GEOLOGICAL ASSESSMENT FOR
U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD,
BEXAR COUNTY, TEXAS

APPENDIX C:
SOILS MAPS

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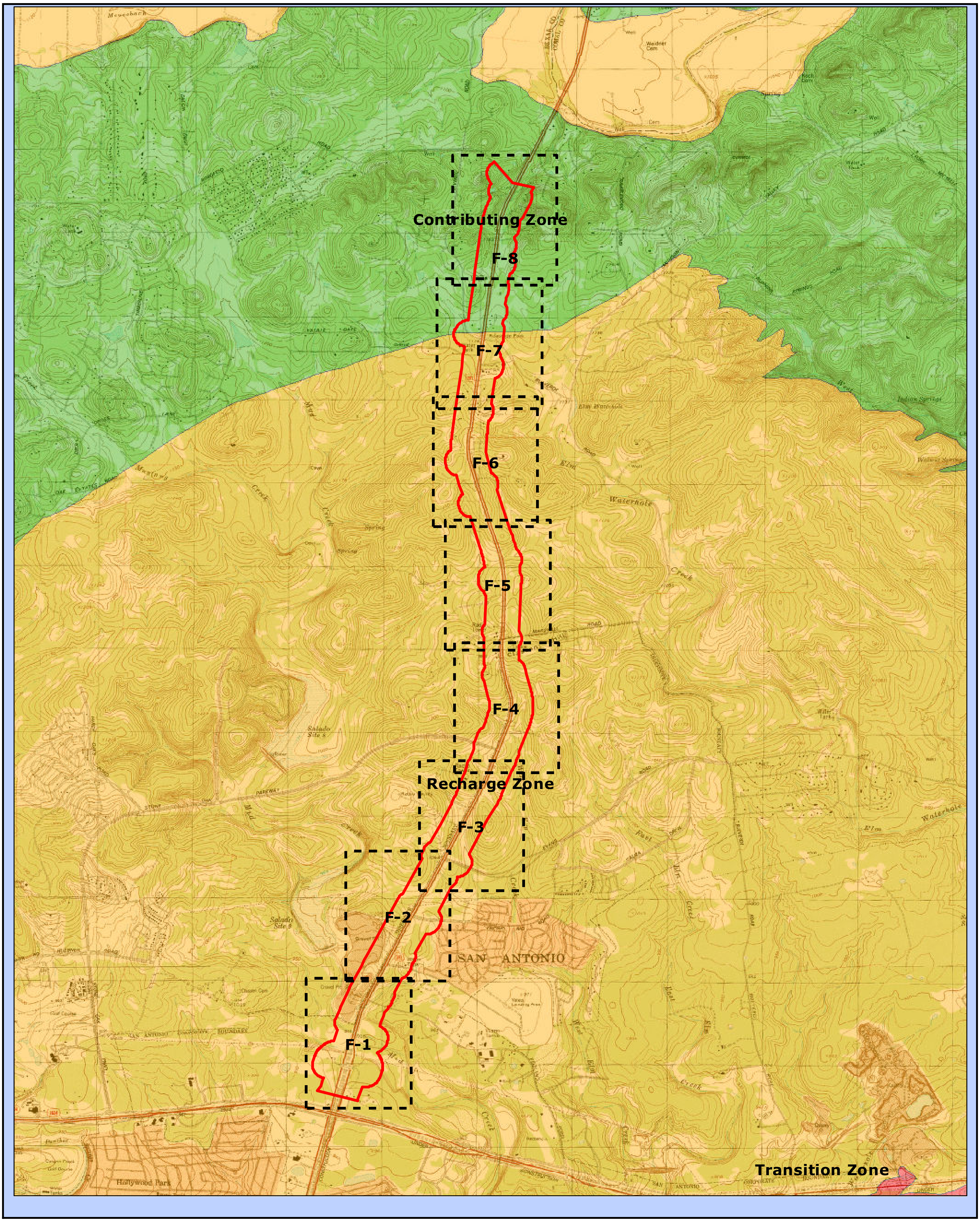

Appendix C-Overview Map

Karst Zones data sources: U.S. Fish and Wildlife Service, 2007
Topographic data source: USGS SIM 2873, 2005

- plate extents
- GA target area
- Contributing Zone
- Contributing Zone within the Transition Zone
- Recharge Zone
- Transition Zone

N
W E
S

Kilometers: 0 1 2 4

Miles: 0 0.5 1 2 3

ZARA ENVIRONMENTAL LLC

STATE OF TEXAS
MARCUS O. GARY
GEOLOGY
10386
LICENSED
PROFESSIONAL GEOSCIENTIST

Marcus O. Gary,
Texas Professional
Geologist No. 10386

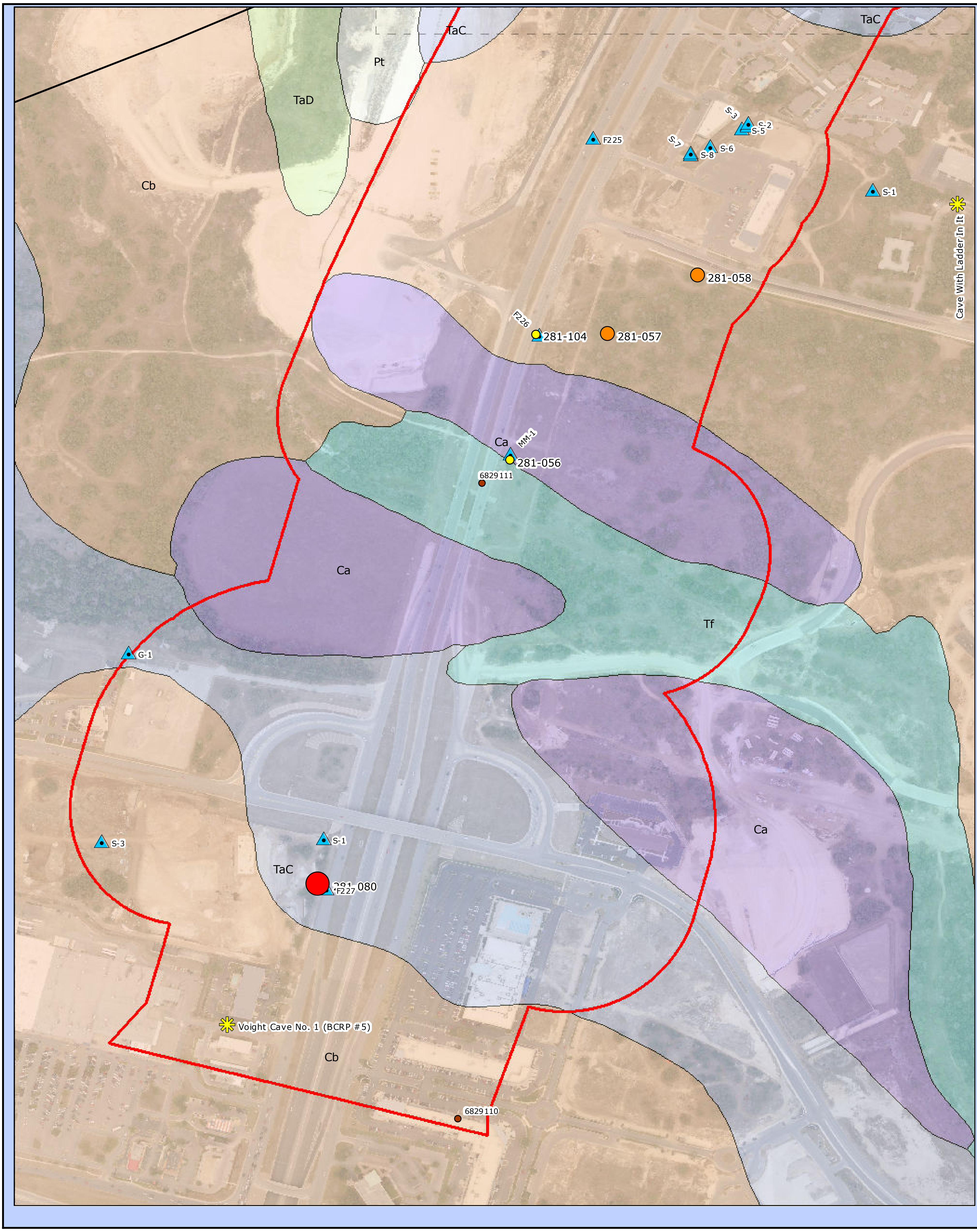

Plate C-1 Soils Map

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

ZARA
ENVIRONMENTAL LLC

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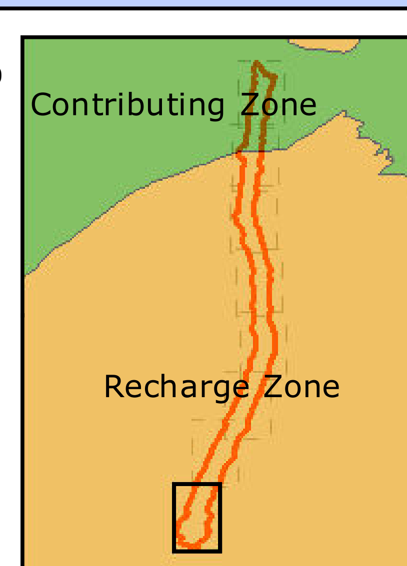
Marcus O. Gary,
Texas Professional Geologist No. 10386

Meters
0 125 250 500
0 375 750 1,500
Feet

N

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area
- BrD - Brackett gravelly clay
- BrE
- BtE - Brackett rock
- Ca - Anhalt clay
- Cb - Crawford and Bexar stony soils
- Kr - Krum
- LvA - Lewisville silty clay
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



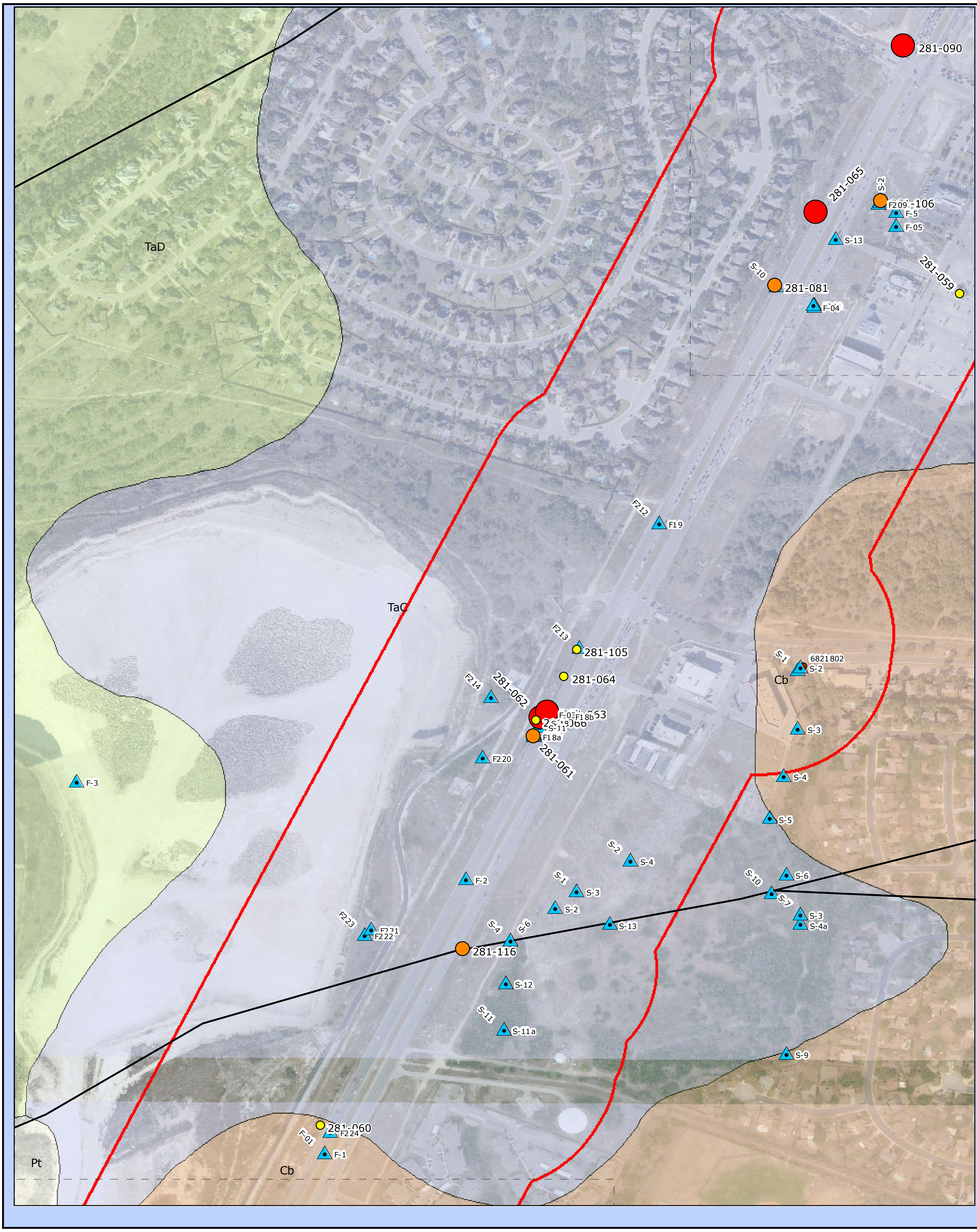


Plate C-2 Soils Map

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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LICENSED
PROFESSIONAL GEOSCIENTIST

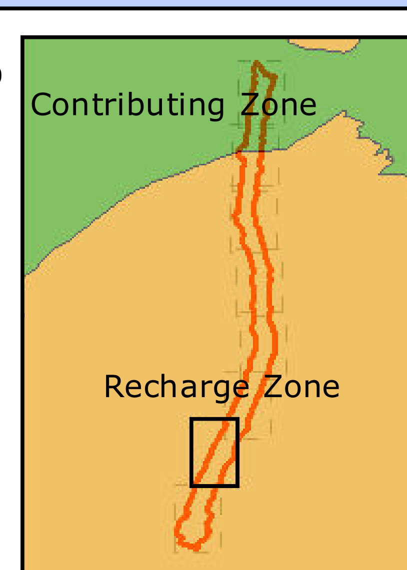
Marcus O. Gary,
Texas Professional Geologist No. 10386

Meters: 0, 125, 250, 500
Feet: 0, 375, 750, 1,500

N

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
- BrD - Brackett gravelly clay
- BrE
- BtE - Brackett rock
- Ca - Anhalt clay
- Cb - Crawford and Bexar stony soils
- Kr - Krum
- LvA - Lewisville silty clay
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



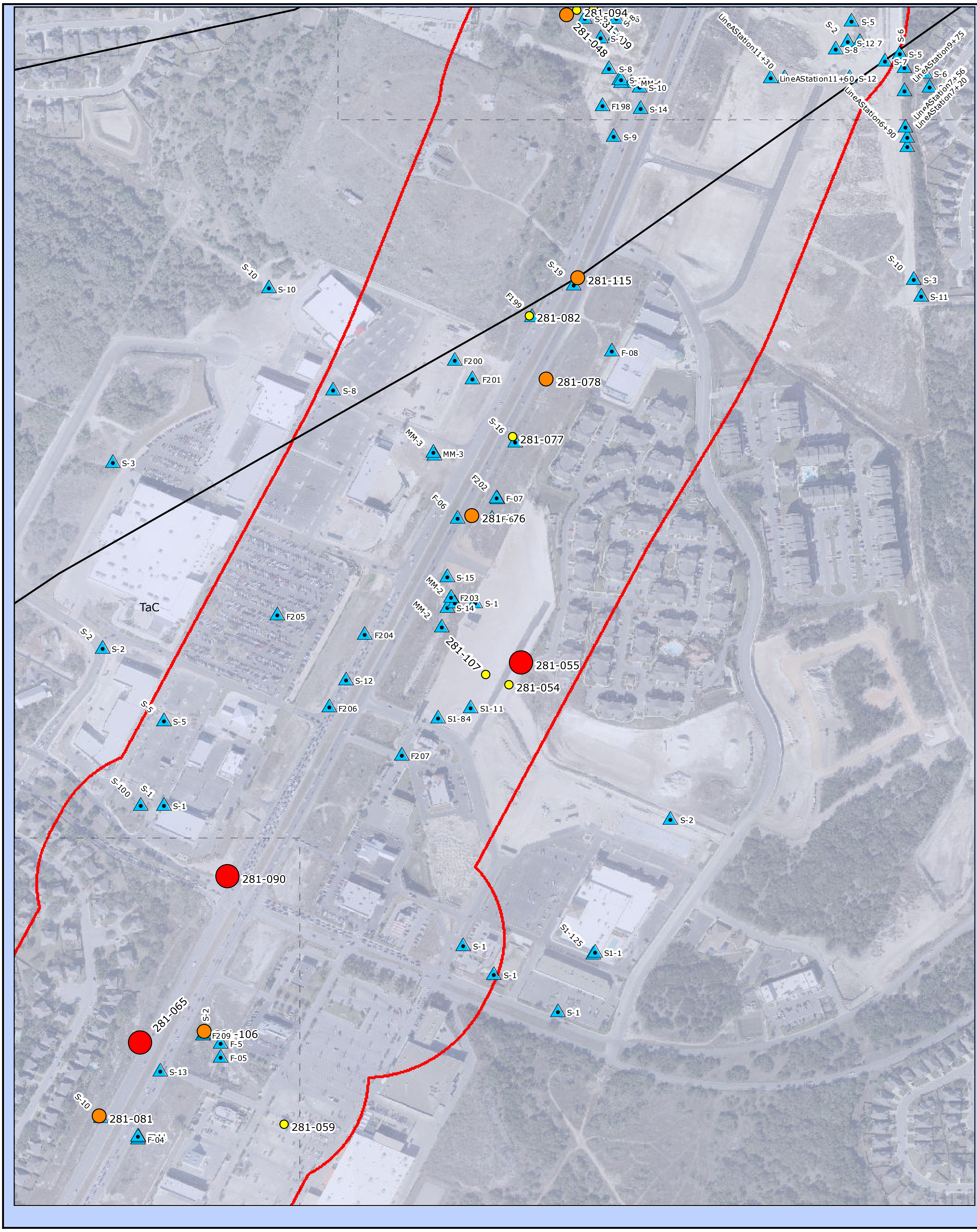


Plate C-3 Soils Map

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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Marcus O. Gary,
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Meters
0 125 250 500
0 375 750 1,500
Feet

N

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
- BrD - Brackett gravelly clay
- BrE
- BtE - Brackett rock
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- Kr - Krum
- LvA - Lewisville silty clay
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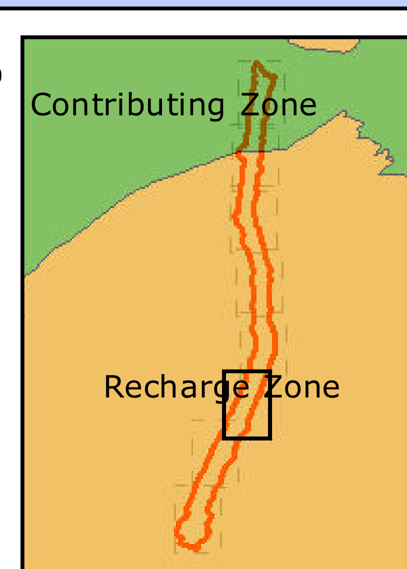
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



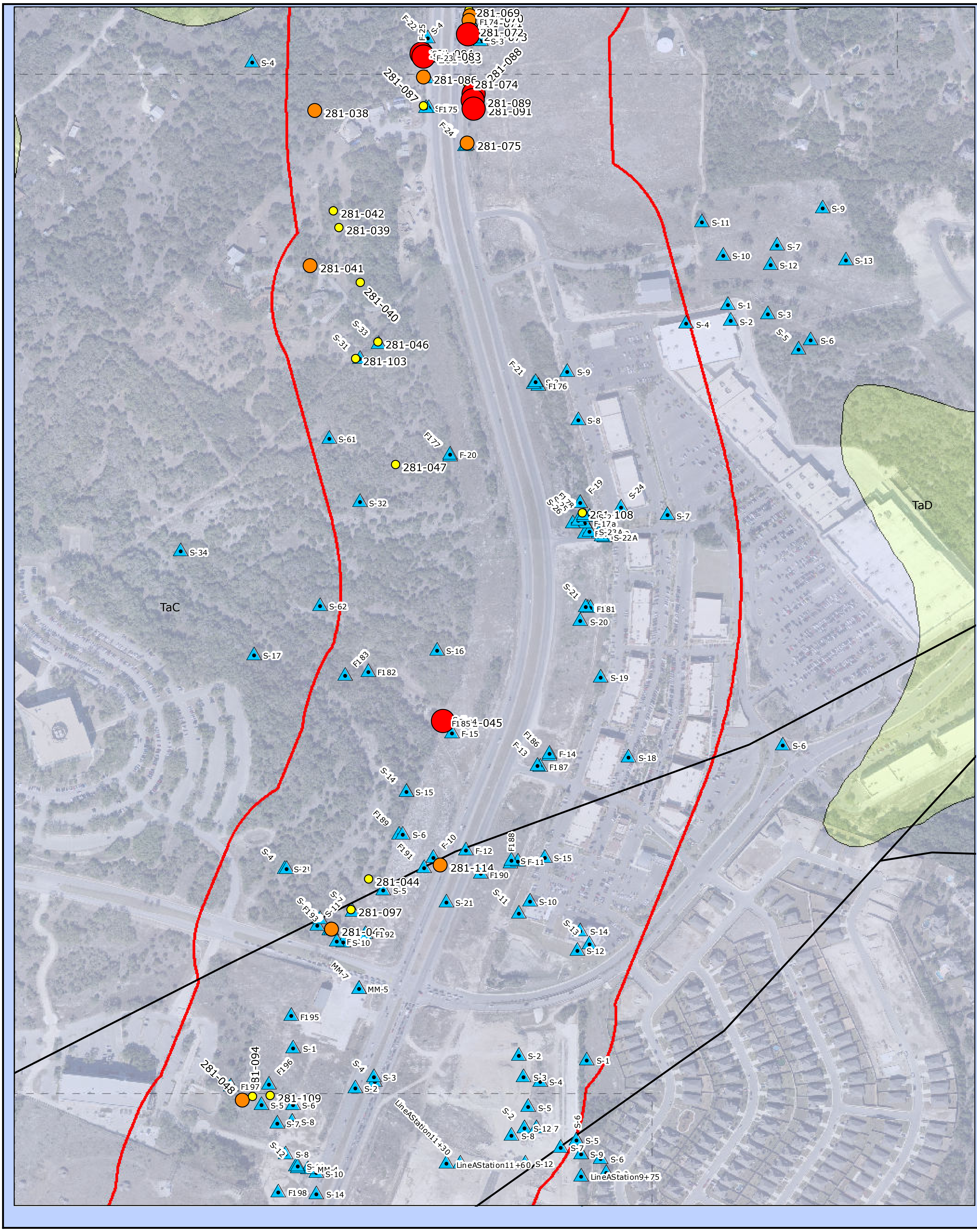


Plate C-4 Soils Map

Meters

0 125 250 500

0 375 750 1,500

Feet

N

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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PROFESSIONAL GEOSCIENTIST LICENSED

Marcus O. Gary,
Texas Professional Geologist No. 10386

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
- BrD - Brackett gravelly clay
- BrE
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- Ca - Anhalt clay
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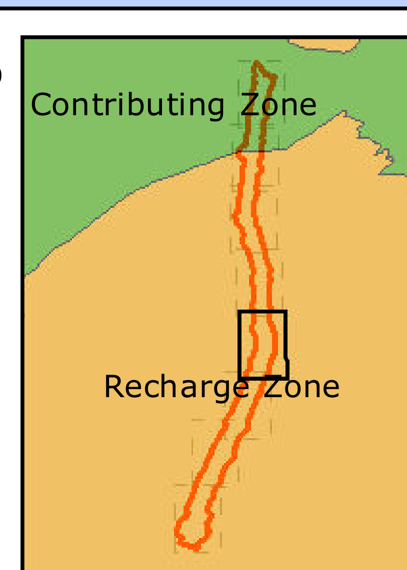
- Kr - Krum
- LvA - Lewisville silty clay
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



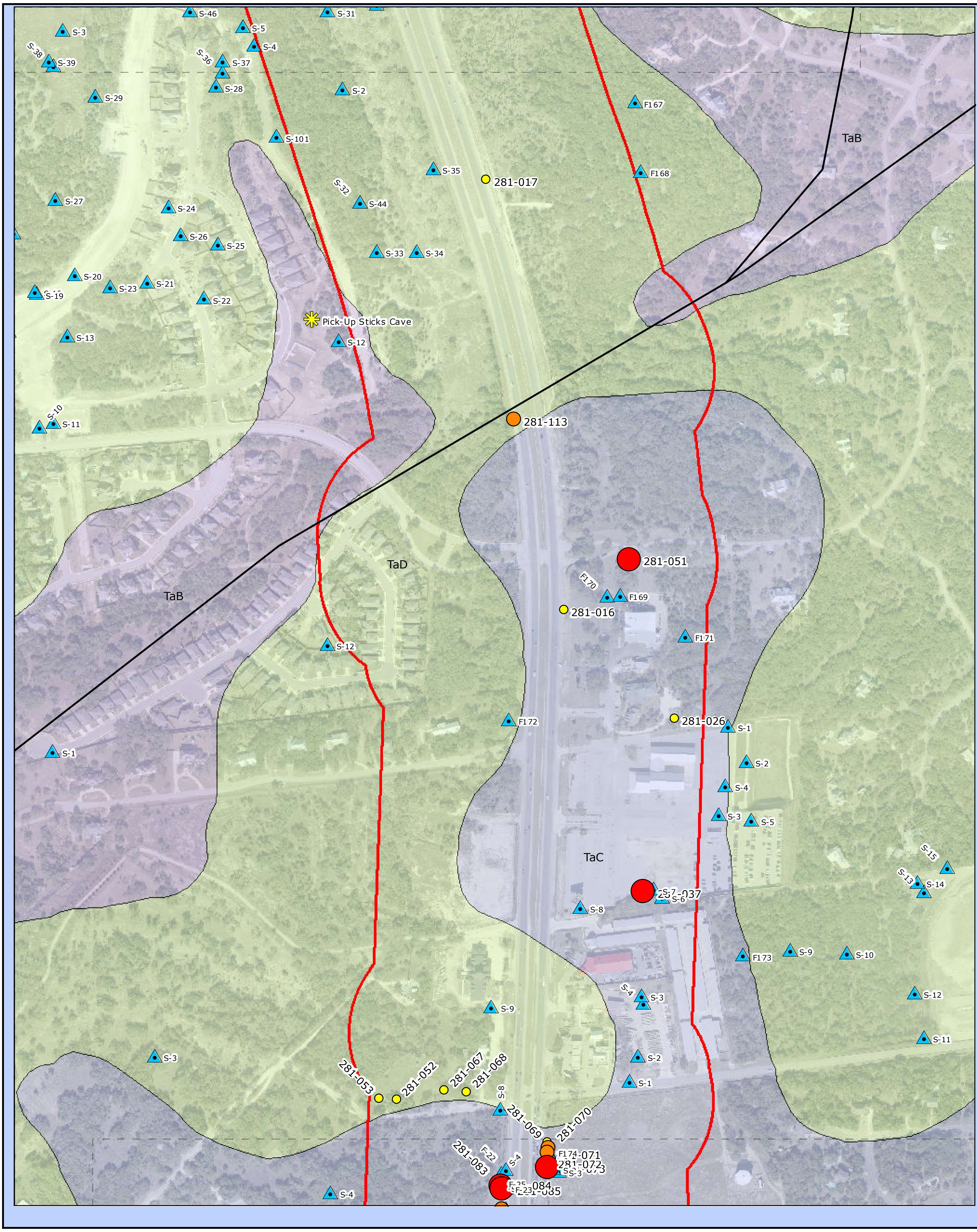


Plate C-5 Soils Map

Meters: 0, 125, 250, 500
Feet: 0, 375, 750, 1,500

N

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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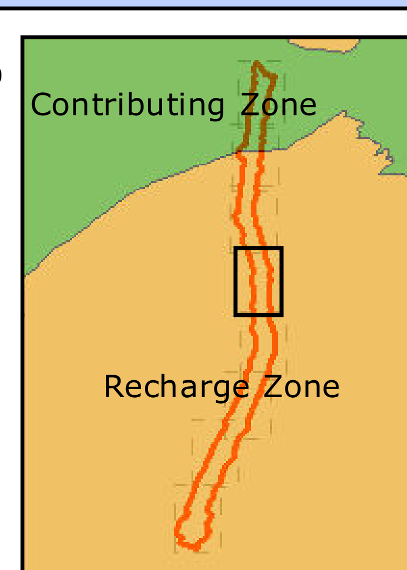
Marcus O. Gary,
Texas Professional Geologist No. 10386

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
- BrD - Brackett gravelly clay
- BrE
- BtE - Brackett rock
- Ca - Anhalt clay
- Cb - Crawford and Bexar stony soils
- Kr - Krum
- LvA - Lewisville silty clay
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



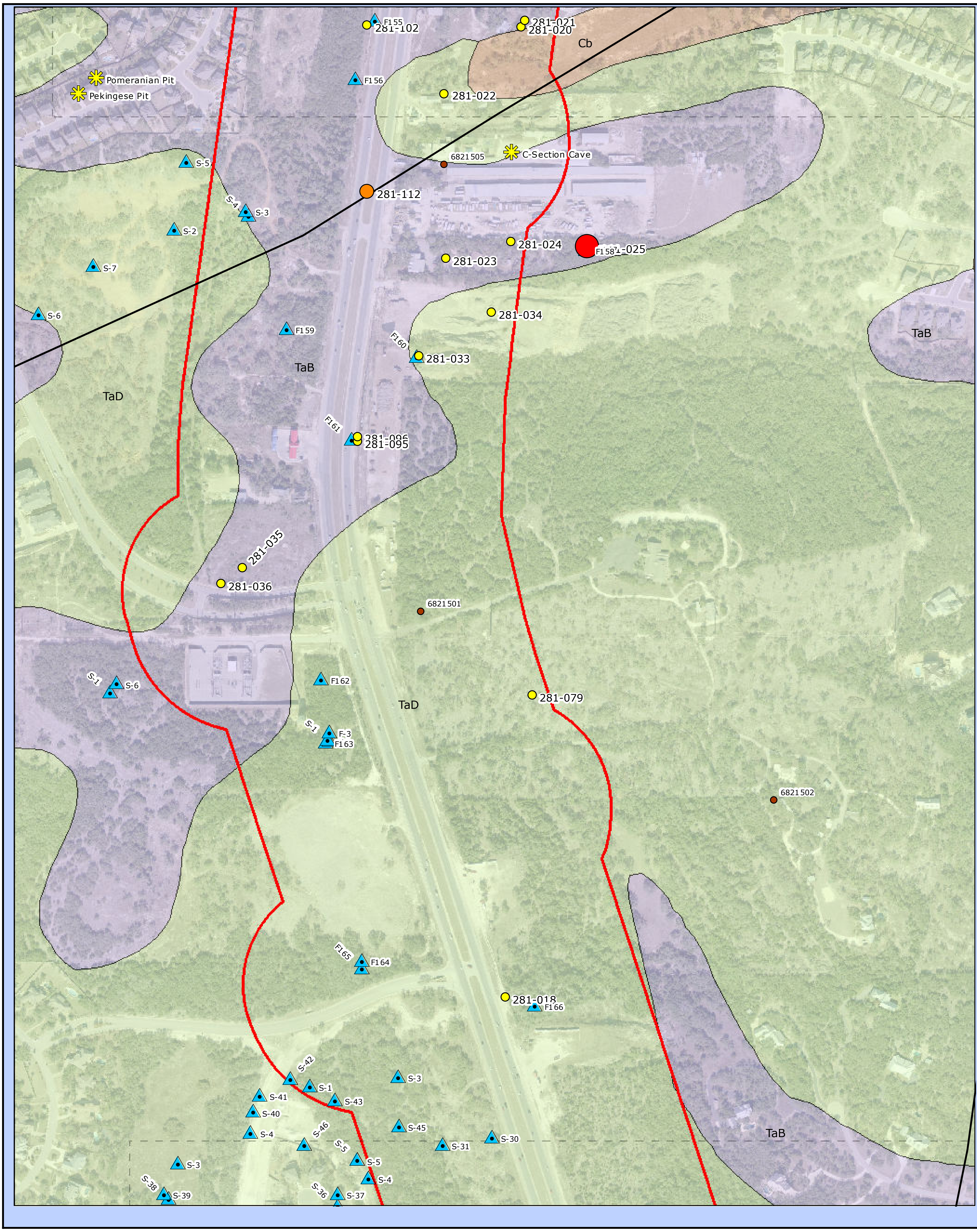


Plate C-6 Soils Map

Meters
0 125 250 500

0 375 750 1,500
Feet

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
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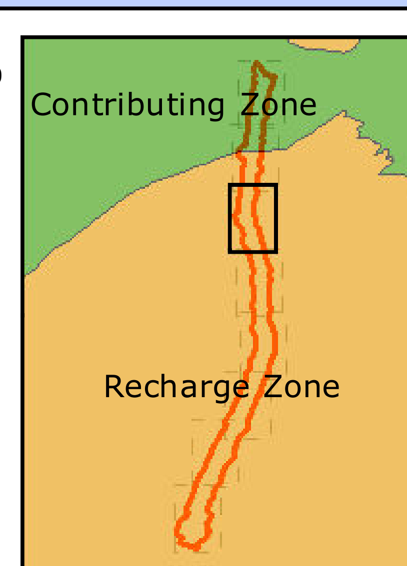
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



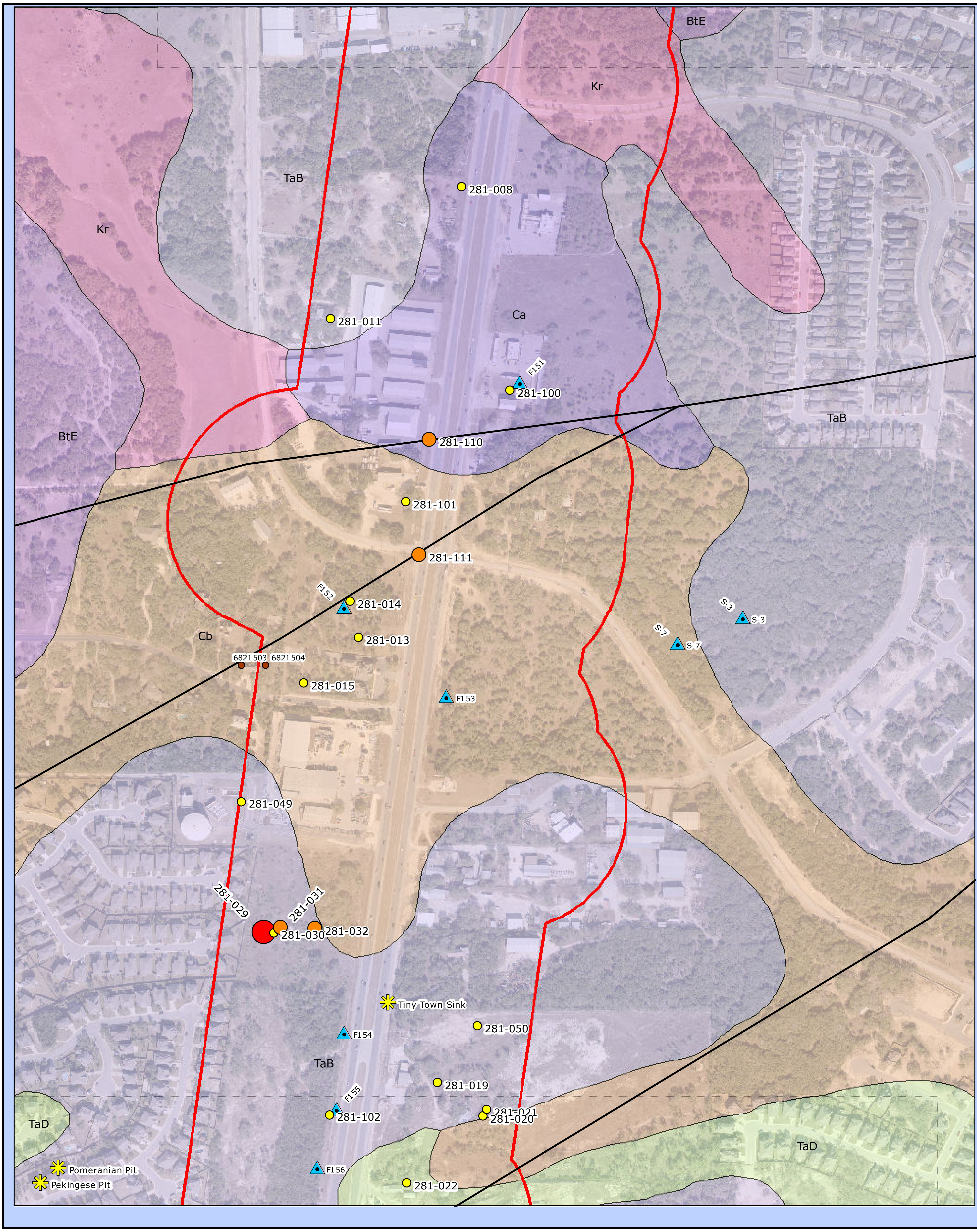


Plate C-7 Soils Map

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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Meters
0 125 250 500
0 375 750 1,500
Feet

N

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
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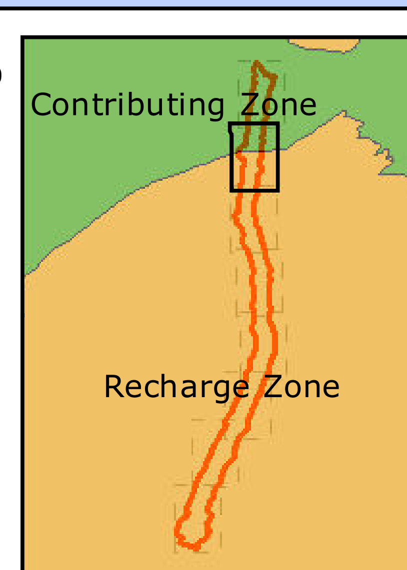
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



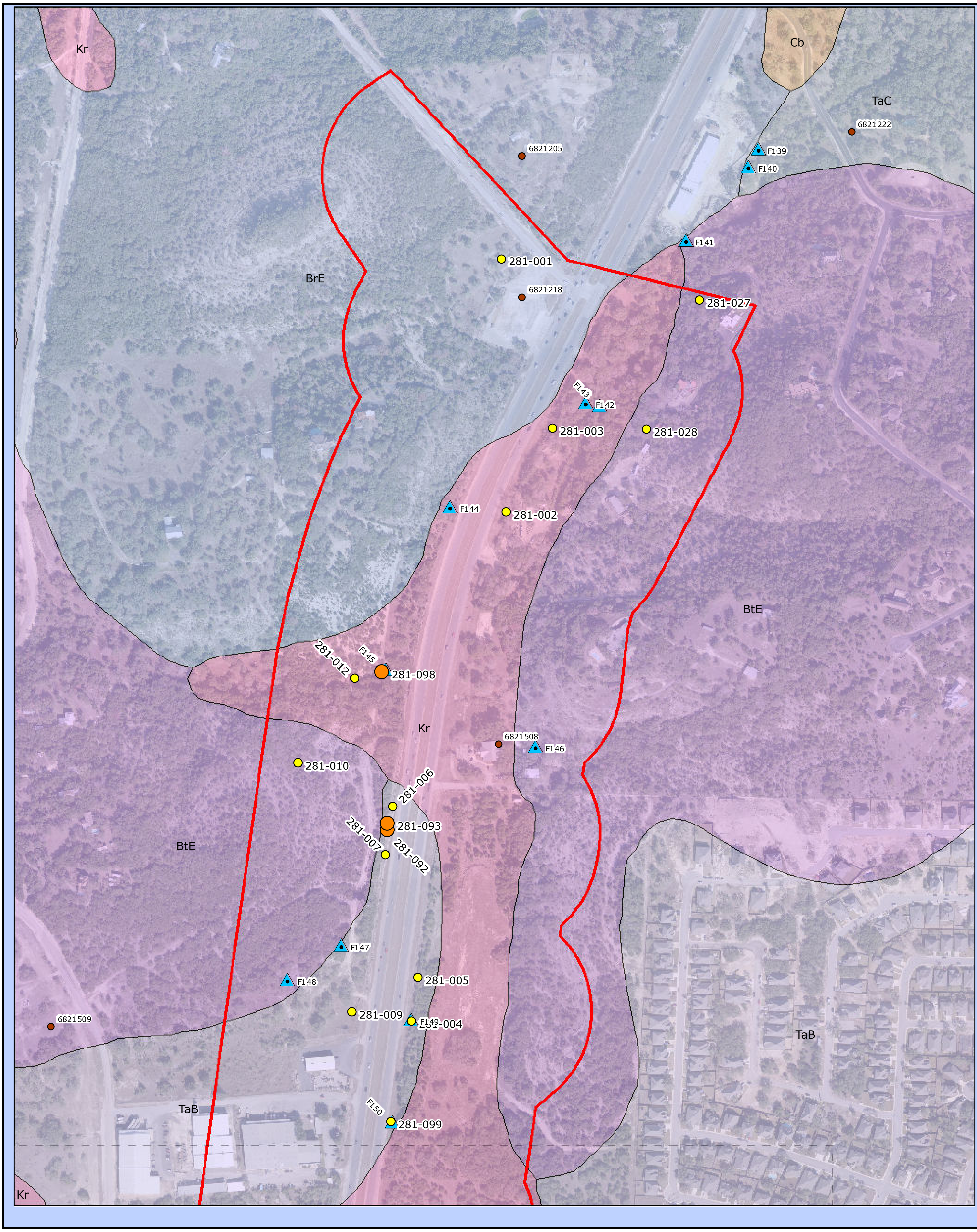


Plate C-8 Soils Map

Soils data source: U.S.D.A. 2010
Aerial Imagery Data: Bexar County Appraisal District, 2009

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Texas Professional Geologist No. 10386

Meters
0 125 250 500
0 375 750 1,500
Feet

N

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Survey Area
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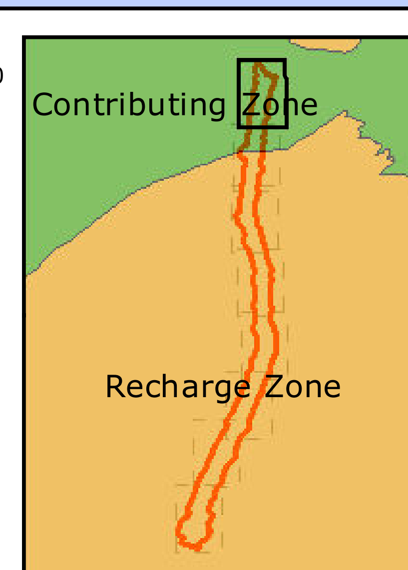
- LvB - Lewisville silty clay
- Or - Orif soils
- TaB - Eckrant cobbly clay
- TaC - Eckrant cobbly clay
- TaD - Eckrant cobbly clay
- Tf Tinn and Frio soils



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GEOLOGICAL ASSESSMENT FOR
U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD,
BEXAR COUNTY, TEXAS

APPENDIX D:
GEOLOGIC MAPS

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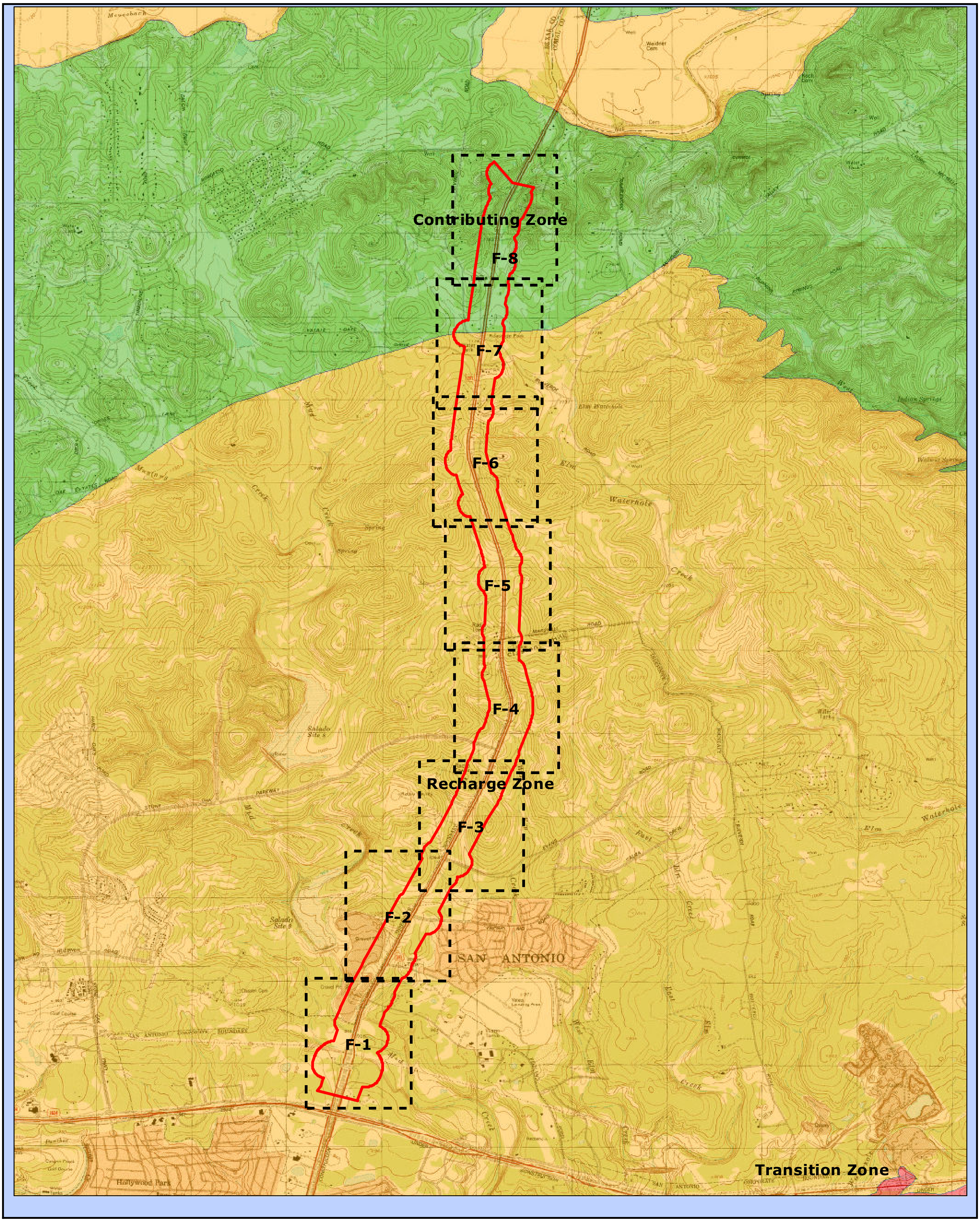

Appendix D-Overview Map

Draft

Karst Zones data sources: U.S. Fish and Wildlife Service, 2007
Topographic data source: USGS SIM 2873, 2005

plate extents
GA target area
Contributing Zone
Contributing Zone within the Transition Zone
Recharge Zone
Transition Zone

N
W E
S

Kilometers
0 1 2 4
0 0.5 1 2 3
Miles

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Texas Professional
Geologist No. 10386

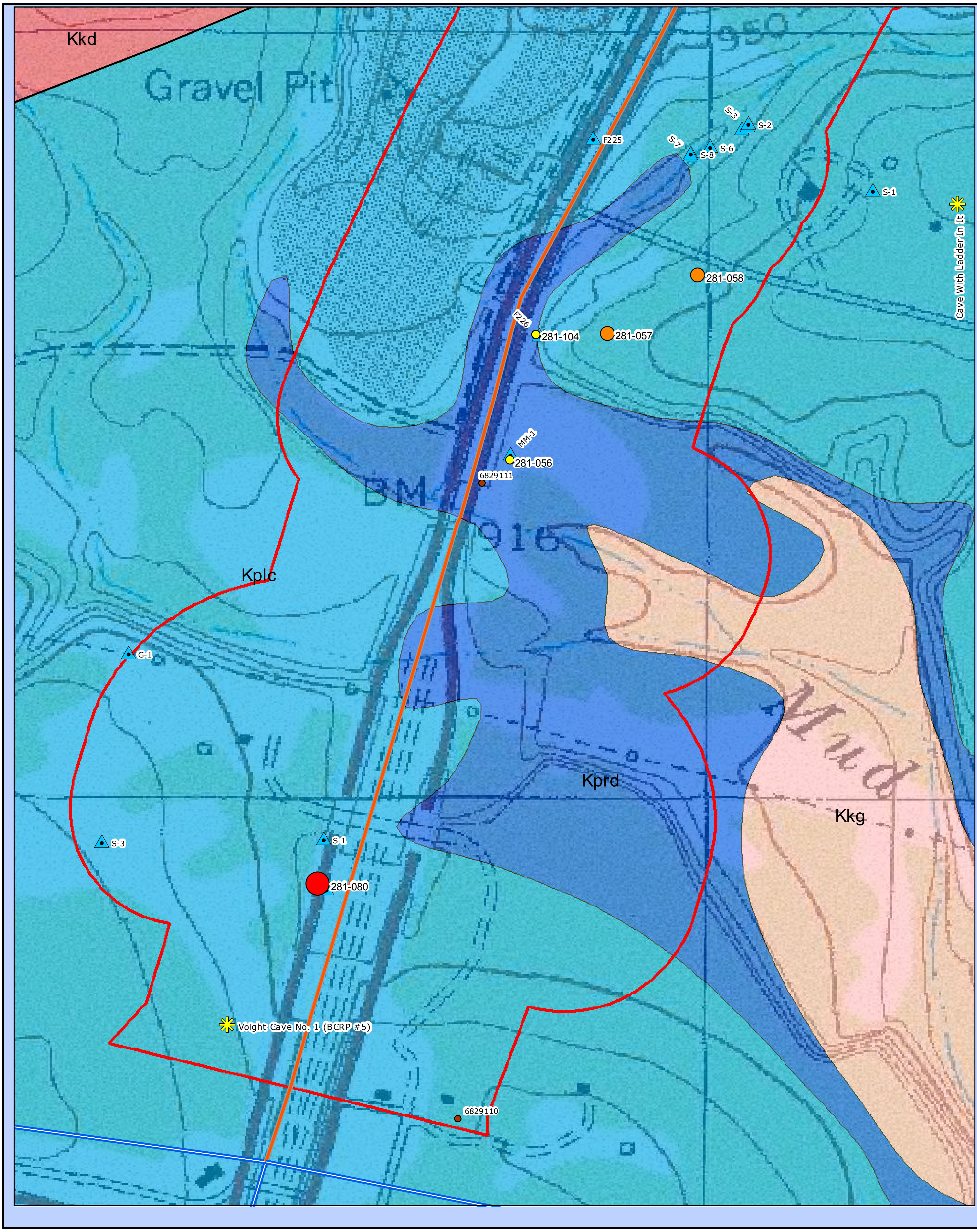
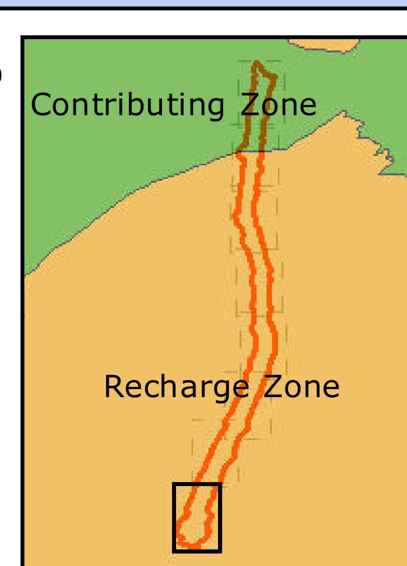


Plate D-1 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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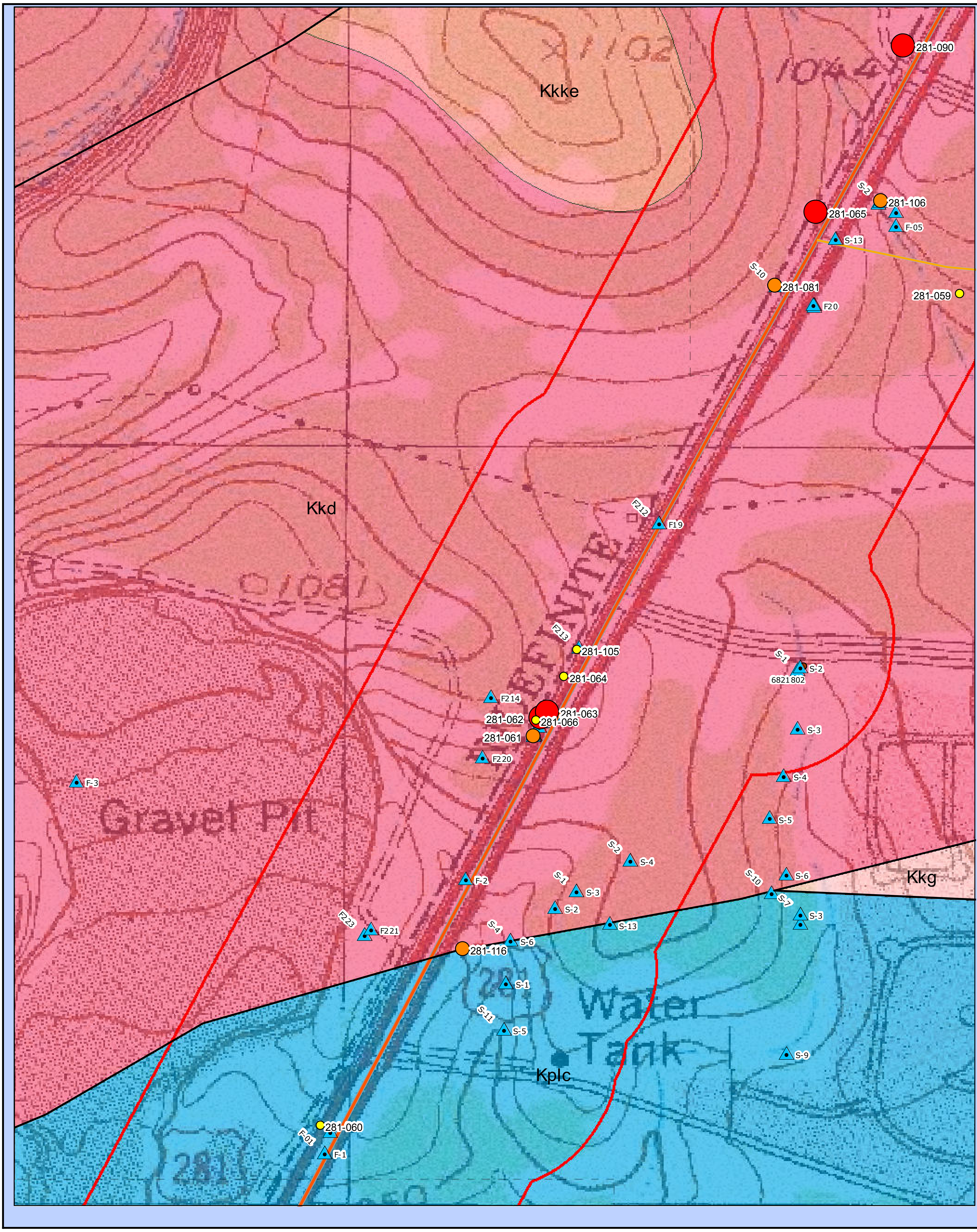

Plate D-2 Geology Map

Meters

0 125 250 500

0 375 750 1,500

Feet

N

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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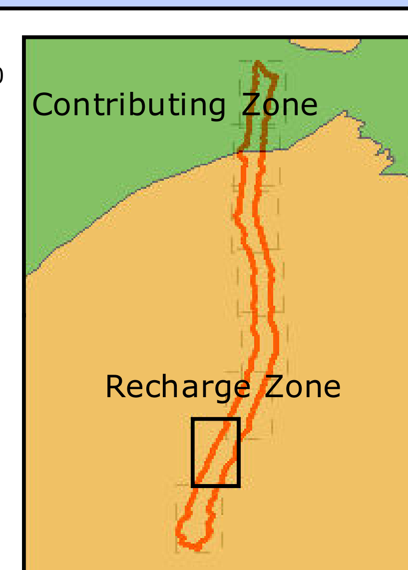
Texas Professional Geologist No. 10386

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



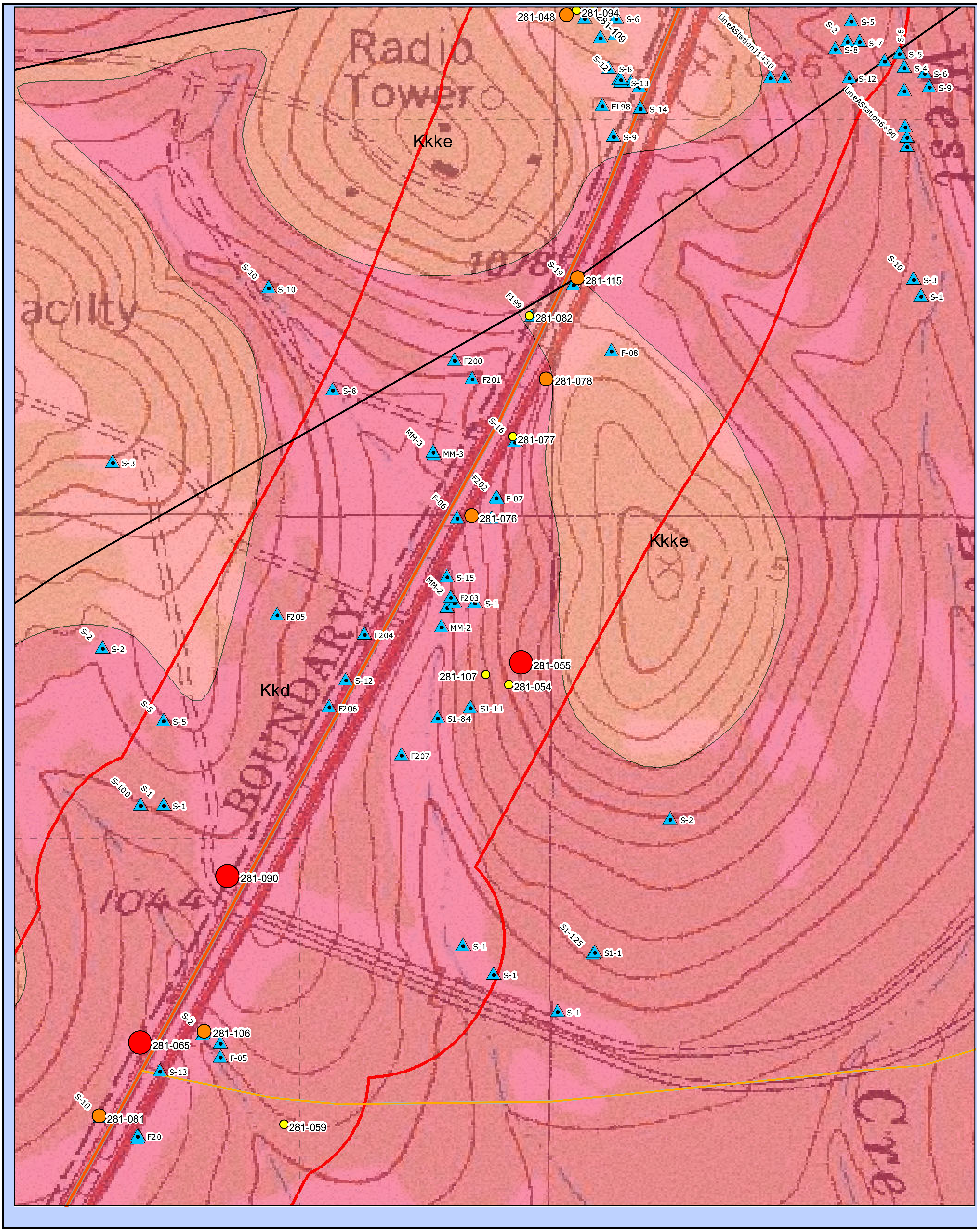


Plate D-3 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

N

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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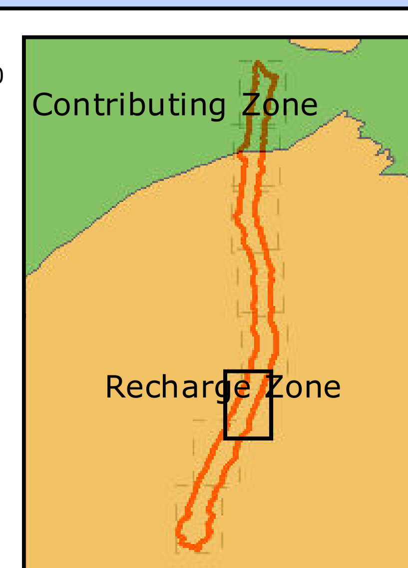
Texas Professional Geologist No. 10386

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



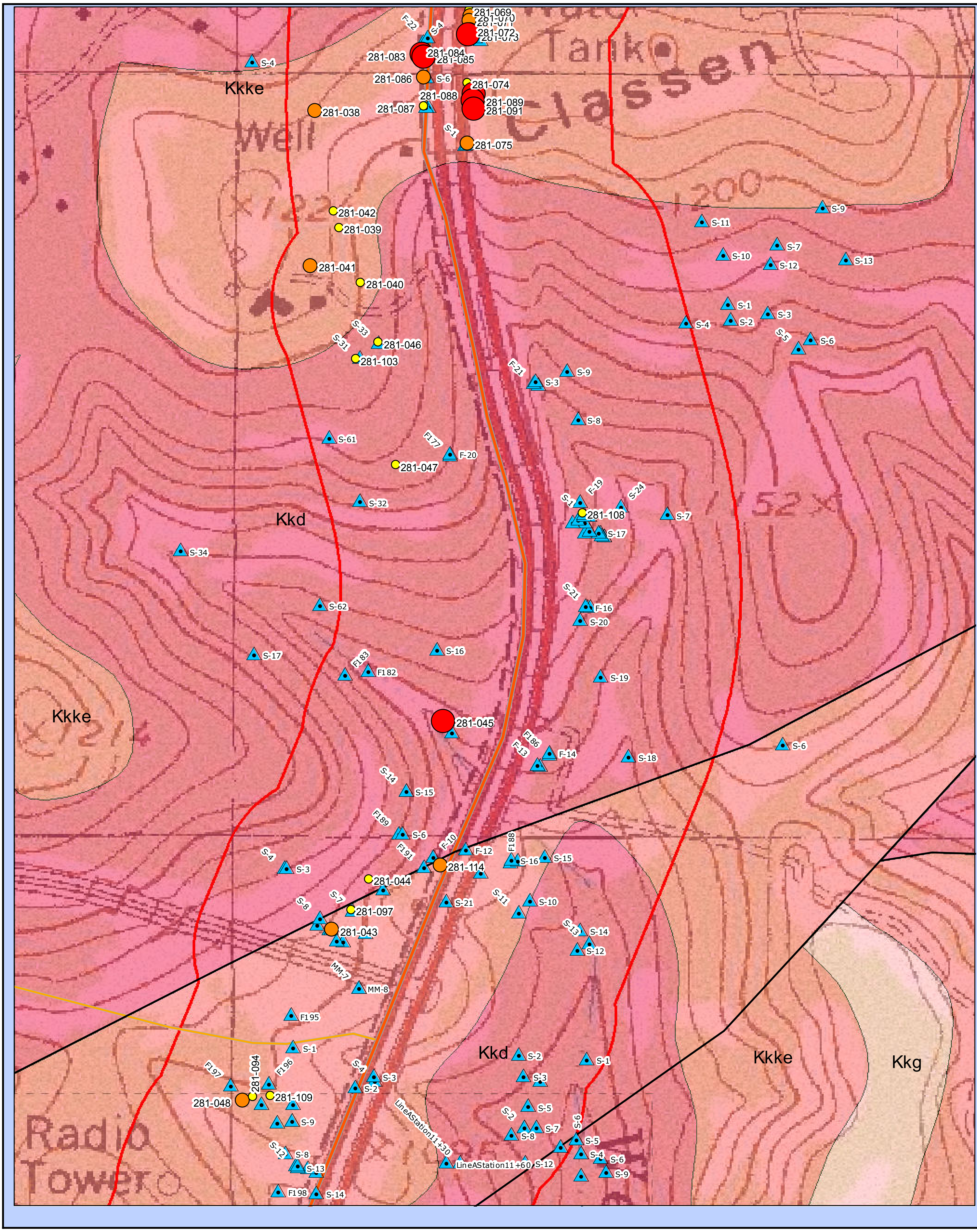


Plate D-4 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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PROFESSIONAL GEOSCIENTIST

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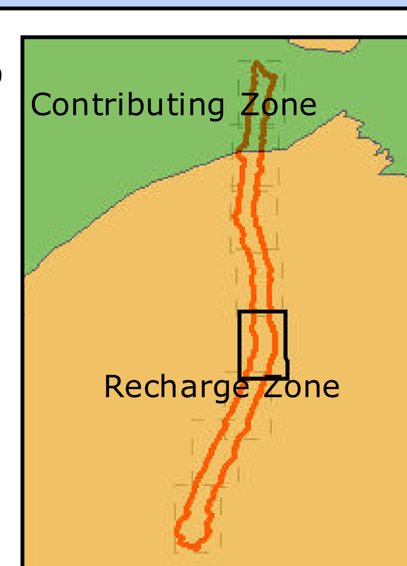
Texas Professional Geologist No. 10386

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



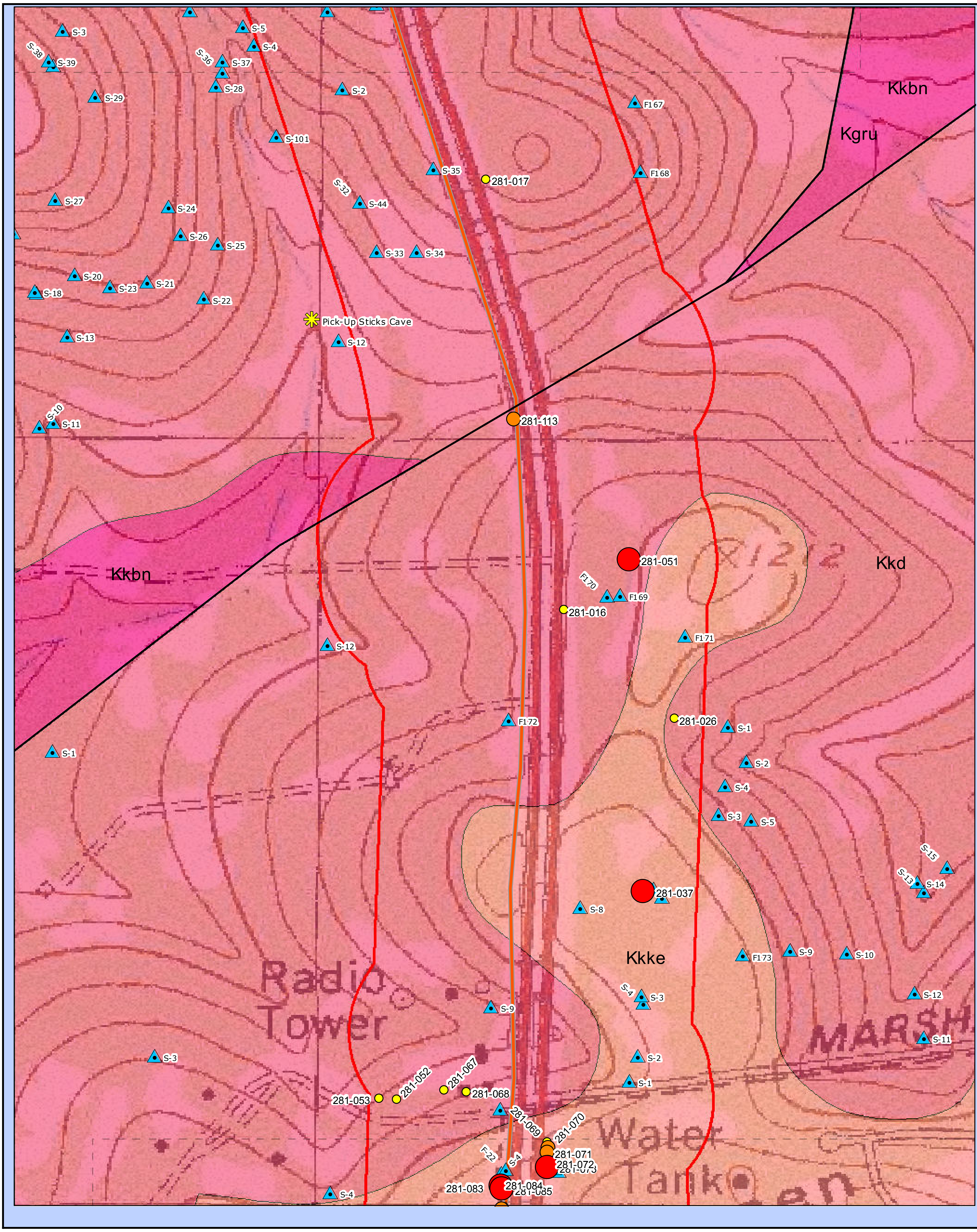


Plate D-5 Geology Map

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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LICENSED
PROFESSIONAL GEOSCIENTIST

Marcus O. Gary,
Texas Professional Geologist No. 10386

Meters
0 125 250 500

0 375 750 1,500
Feet

N

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
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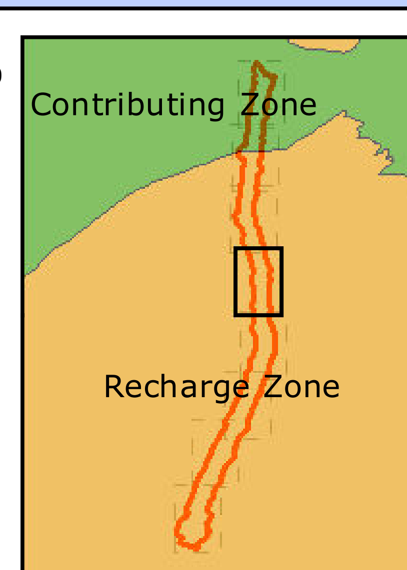
- Kgrl - - Lower Glen Rose



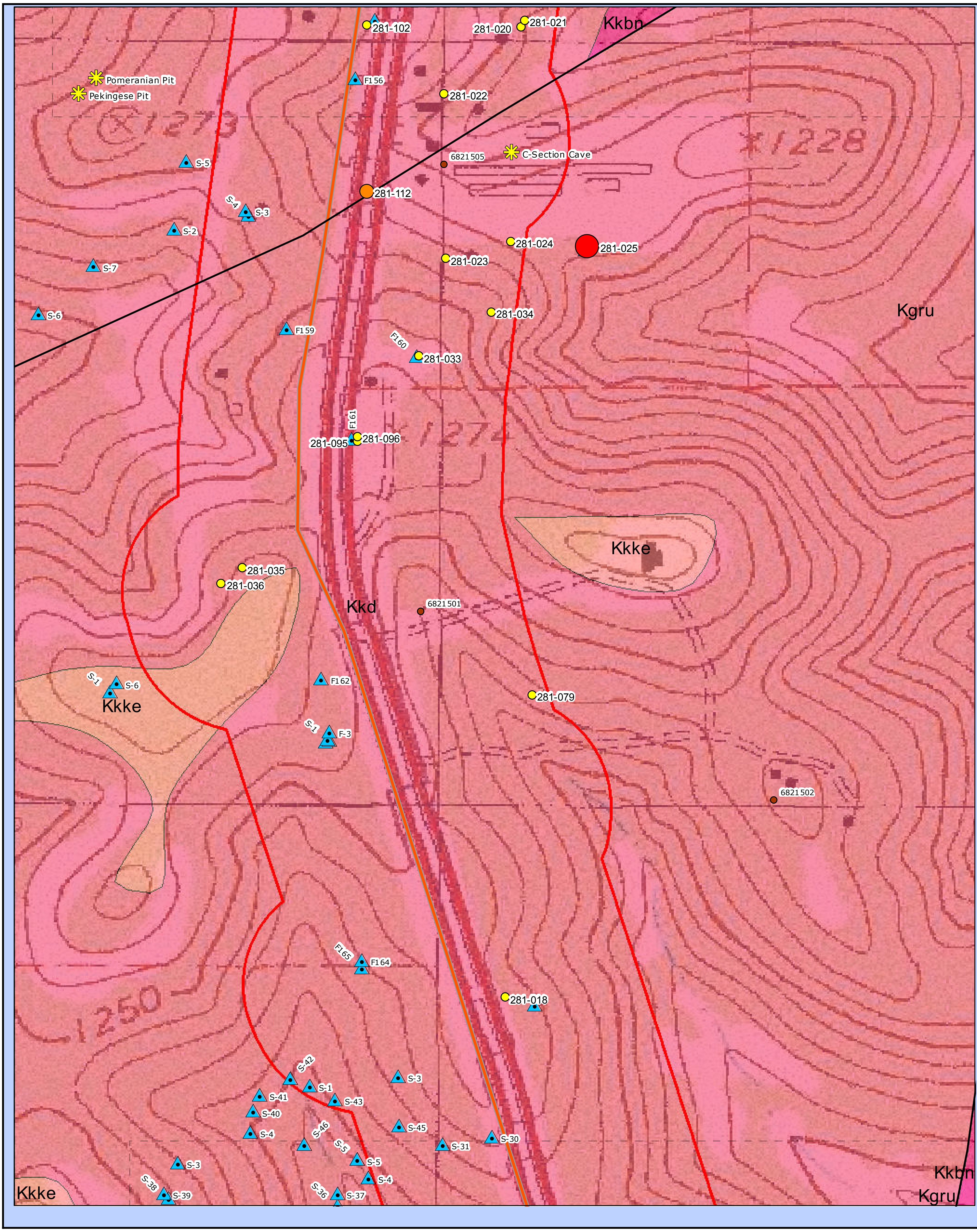


Plate D-6 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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Marcus O. Gary,
Texas Professional Geologist No. 10386

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

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- Georgetown Formation
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- Kplc - Person Fm. - Leached and Collapsed mbr.
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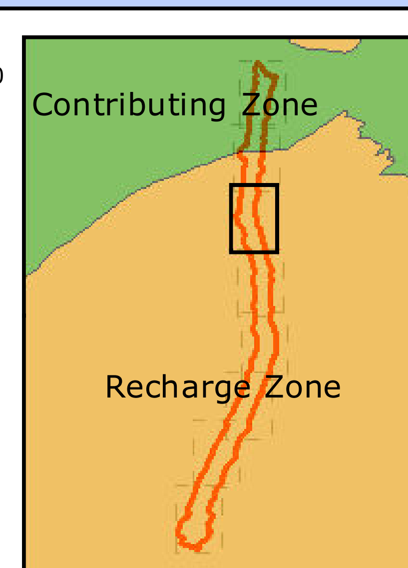
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



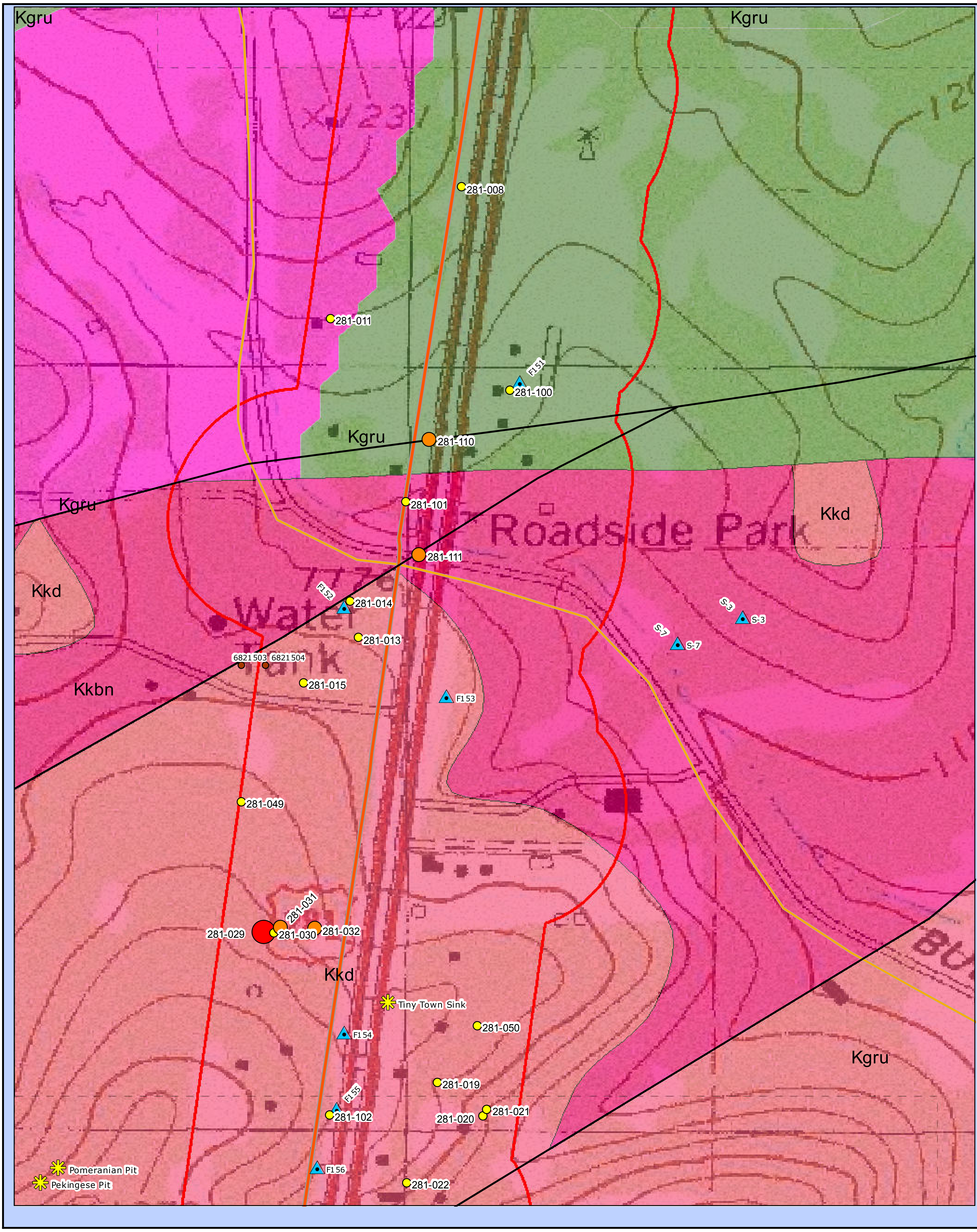


Plate D-7 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

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LICENSED
PROFESSIONAL GEOSCIENTIST

Marcus O. Gary,
Texas Professional Geologist No. 10386

N

Surveyed Features
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose

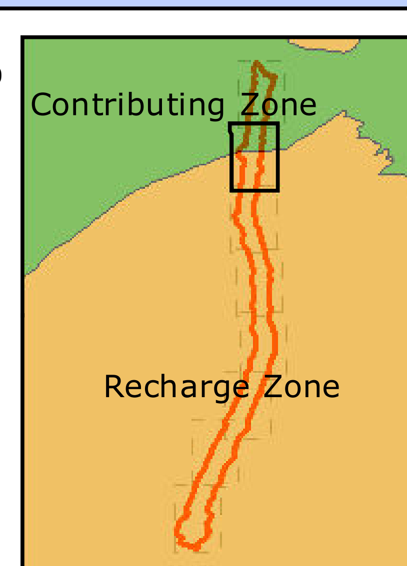

Plate D-8 Geology Map

Meters
0 125 250 500
0 375 750 1,500
Feet

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

ZARA ENVIRONMENTAL LLC

STATE OF TEXAS
MARCUS O. GARY
GEOLOGY
10386
LICENSED
PROFESSIONAL GEOSCIENTIST

Marcus O. Gary,
Texas Professional Geologist No. 10386

Surveyed Features

- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
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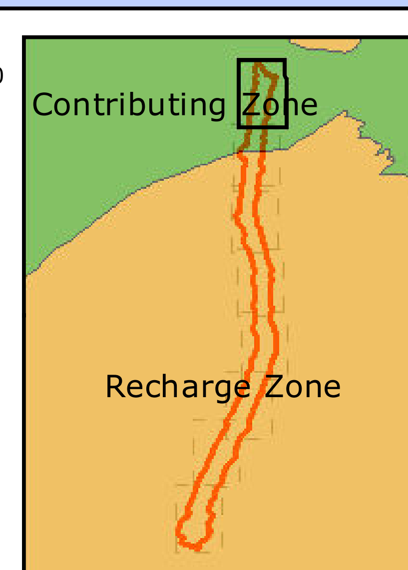
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose



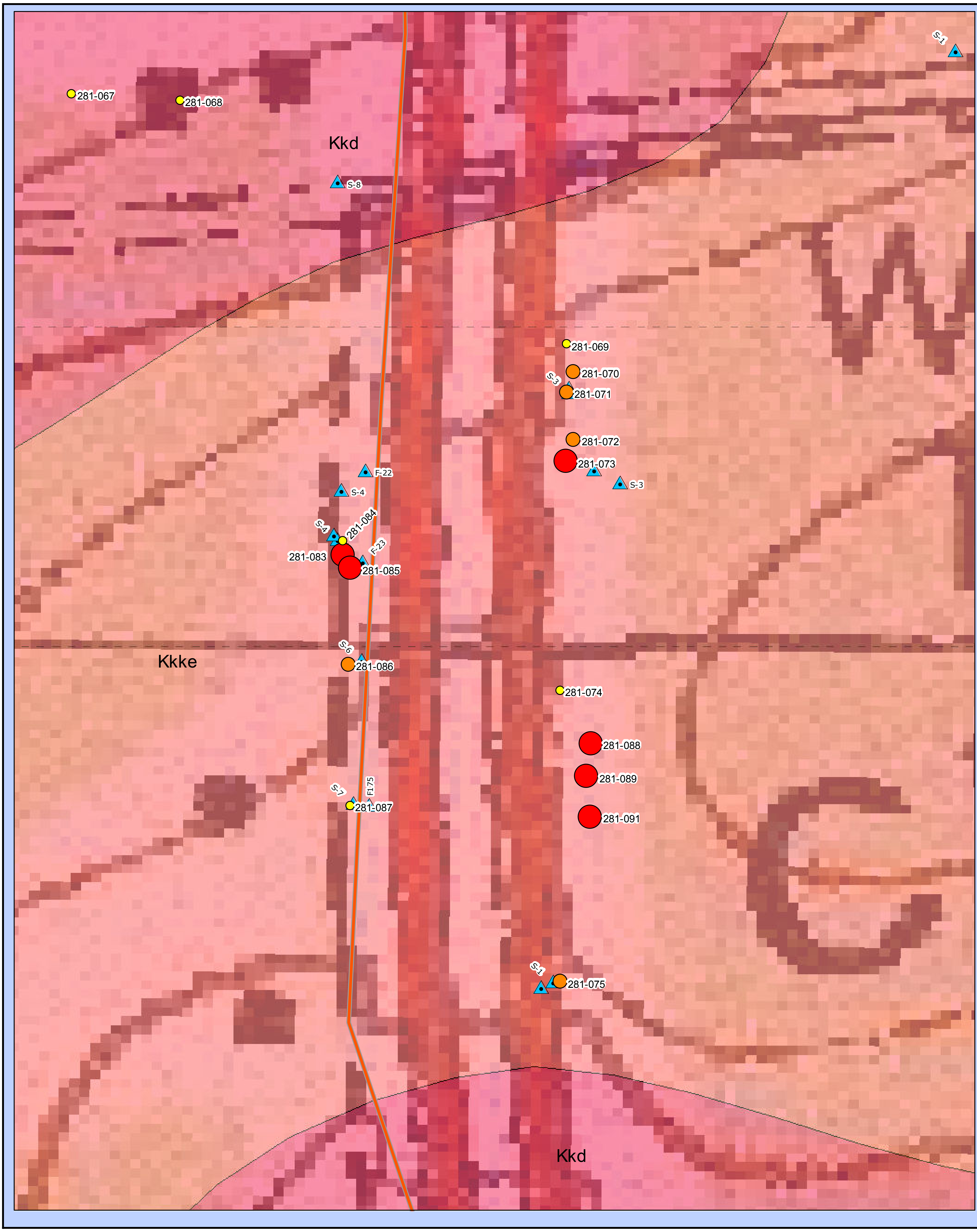


Plate C-9 Geology Map

Meters: 0, 25, 50, 100

Feet: 0, 80, 160, 320

N

Geology data sources: USGS SIM 2873, 2005
TNRIS, Geologic Atlas of Texas, 2010

ZARA
ENVIRONMENTAL LLC

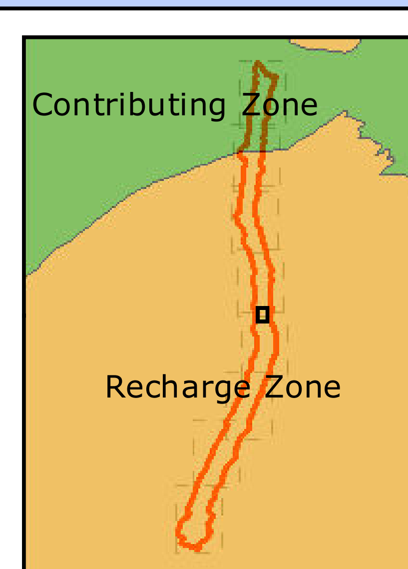
STATE OF TEXAS — MARCUS O. GARY — GEOLOGY — 10386 — LICENSED — PROFESSIONAL GEOSCIENTIST

Marcus O. Gary,
Texas Professional Geologist No. 10386

Surveyed Features

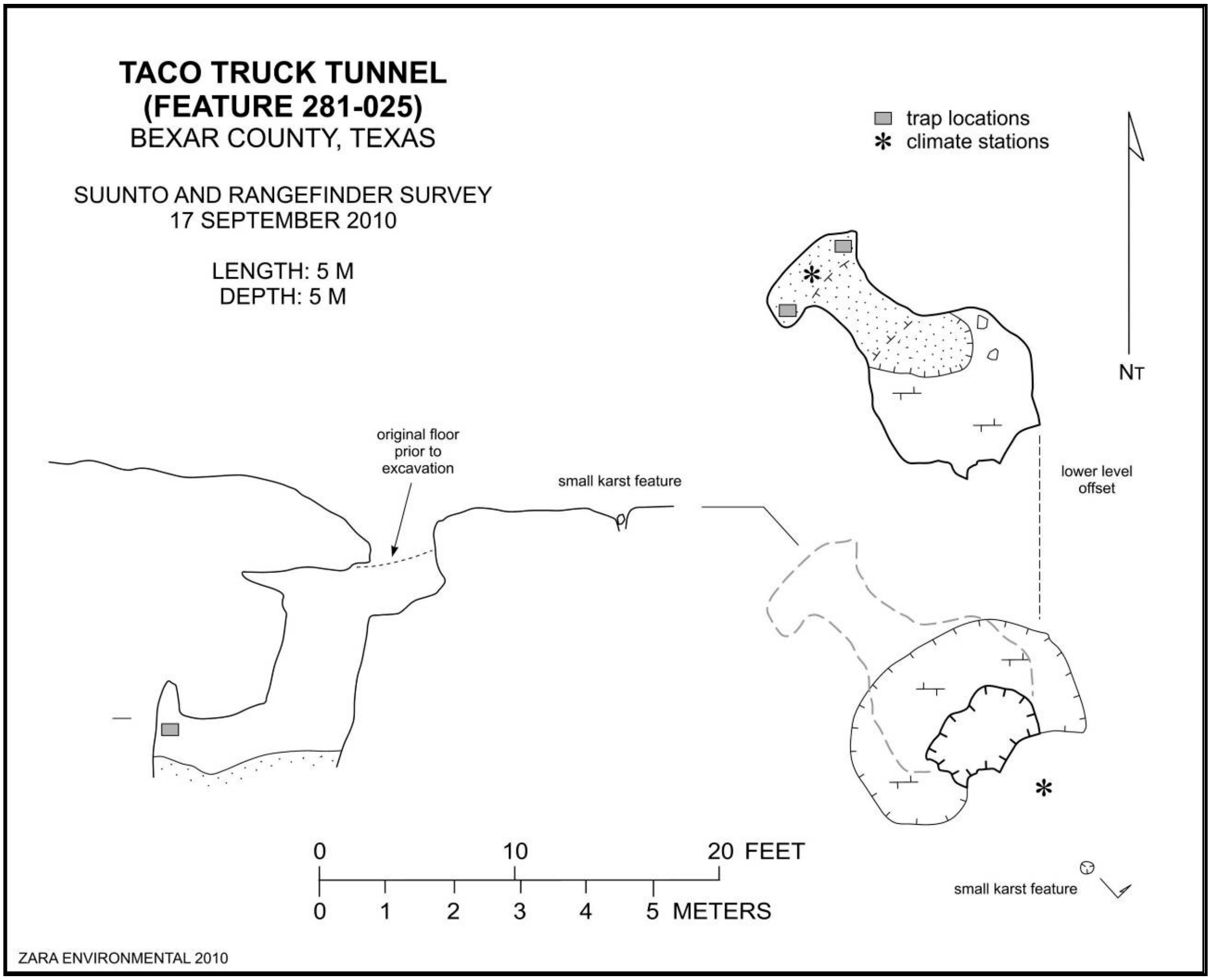
- 10.000000 - 39.000000
- 39.000001 - 50.000000
- 50.000001 - 80.000000
- historic_features_clipped_extent
- Historic Caves (TSS)
- Wells
- plate extents
- GA Study Area

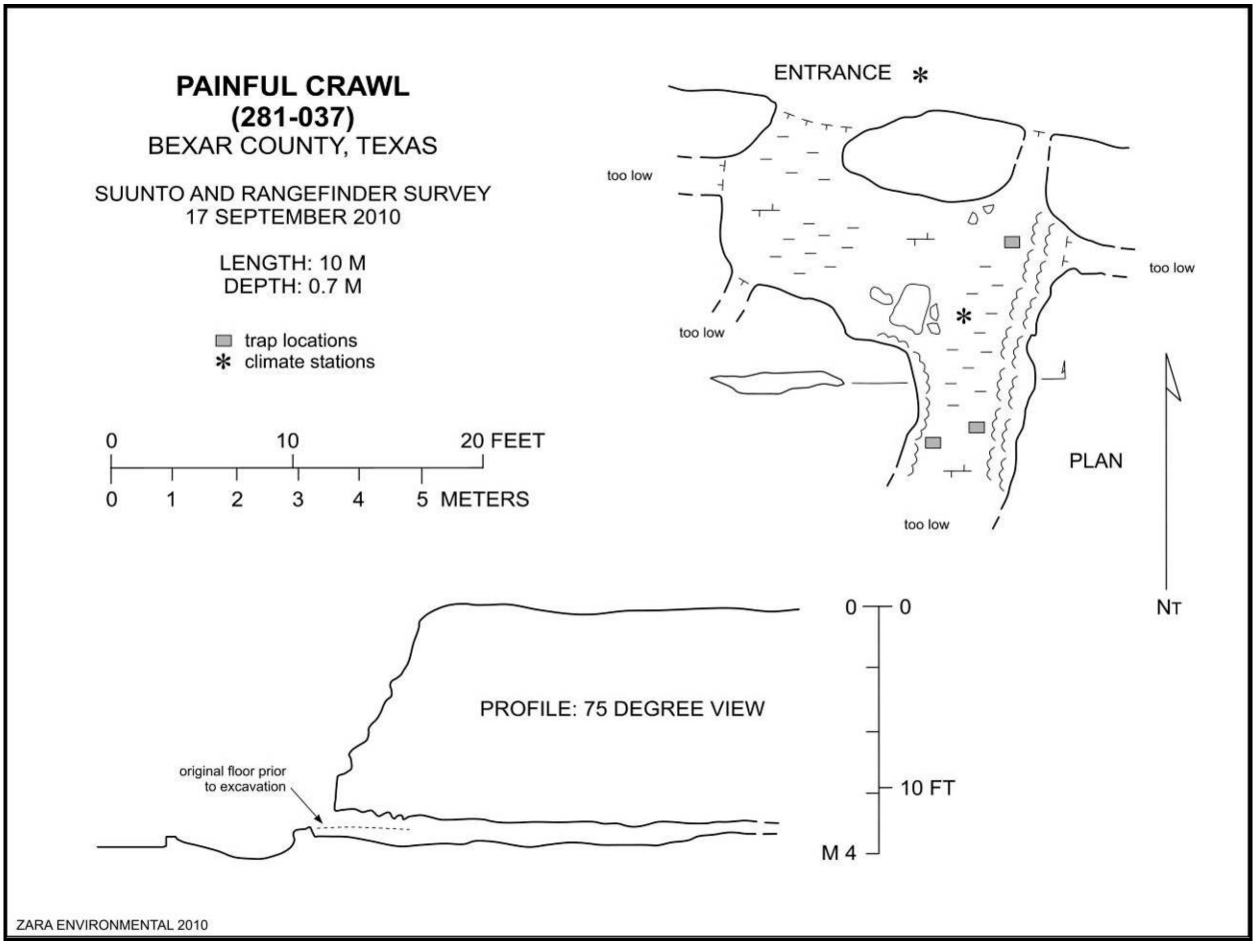
- Upper Confining Units
- Georgetown Formation
- Kpcm - Person Fm. - Cyclic and Marine mbr.
- Kplc - Person Fm. - Leached and Collapsed mbr.
- Kprd - Person Fm. - Regional Dense mbr.
- Kkg - Kainer Fm. - Grainstone mbr.
- Kkke - Kainer Fm. - Kirschberg Evaporite mbr.
- Kkd - Kainer Fm. - Dolomitic mbr.
- Kkbn - Kainer Fm. - Basal Nodular mbr.
- Ked - Edwards undivided
- Kgru - Upper Glen Rose
- Kgrl - - Lower Glen Rose

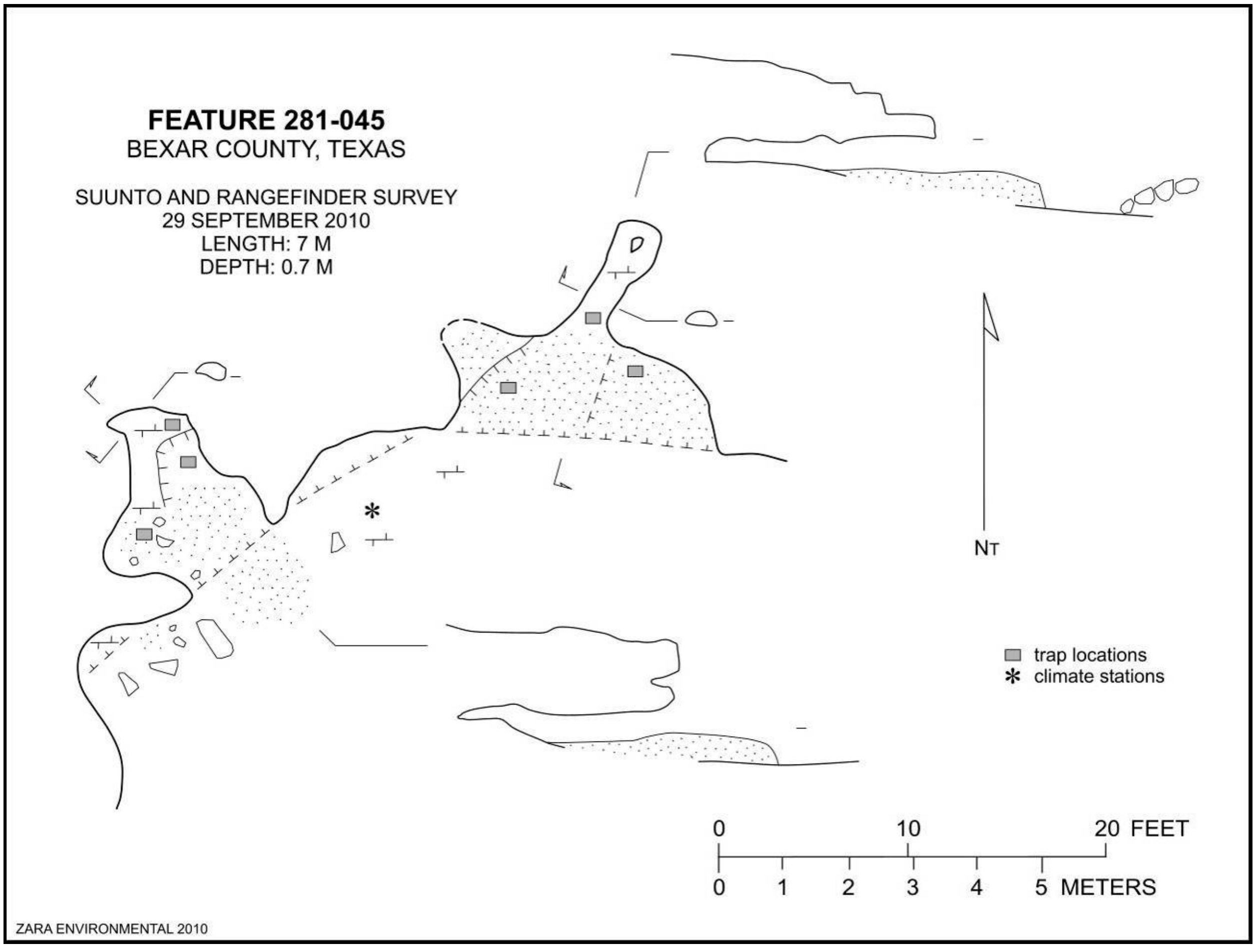


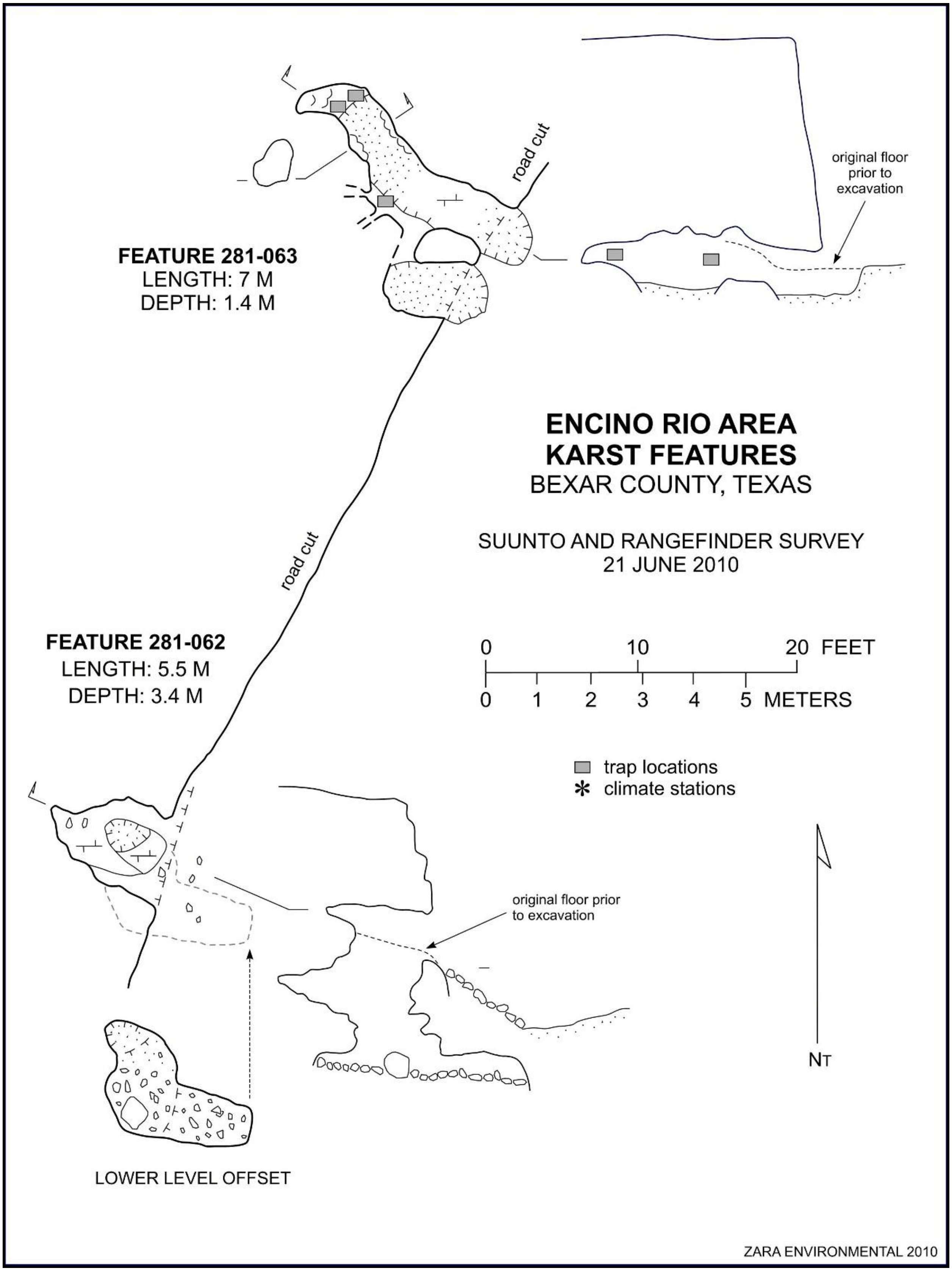
GEOLOGICAL ASSESSMENT FOR
U. S. 281 FROM LOOP 1604 TO BORGFELD ROAD,
BEXAR COUNTY, TEXAS

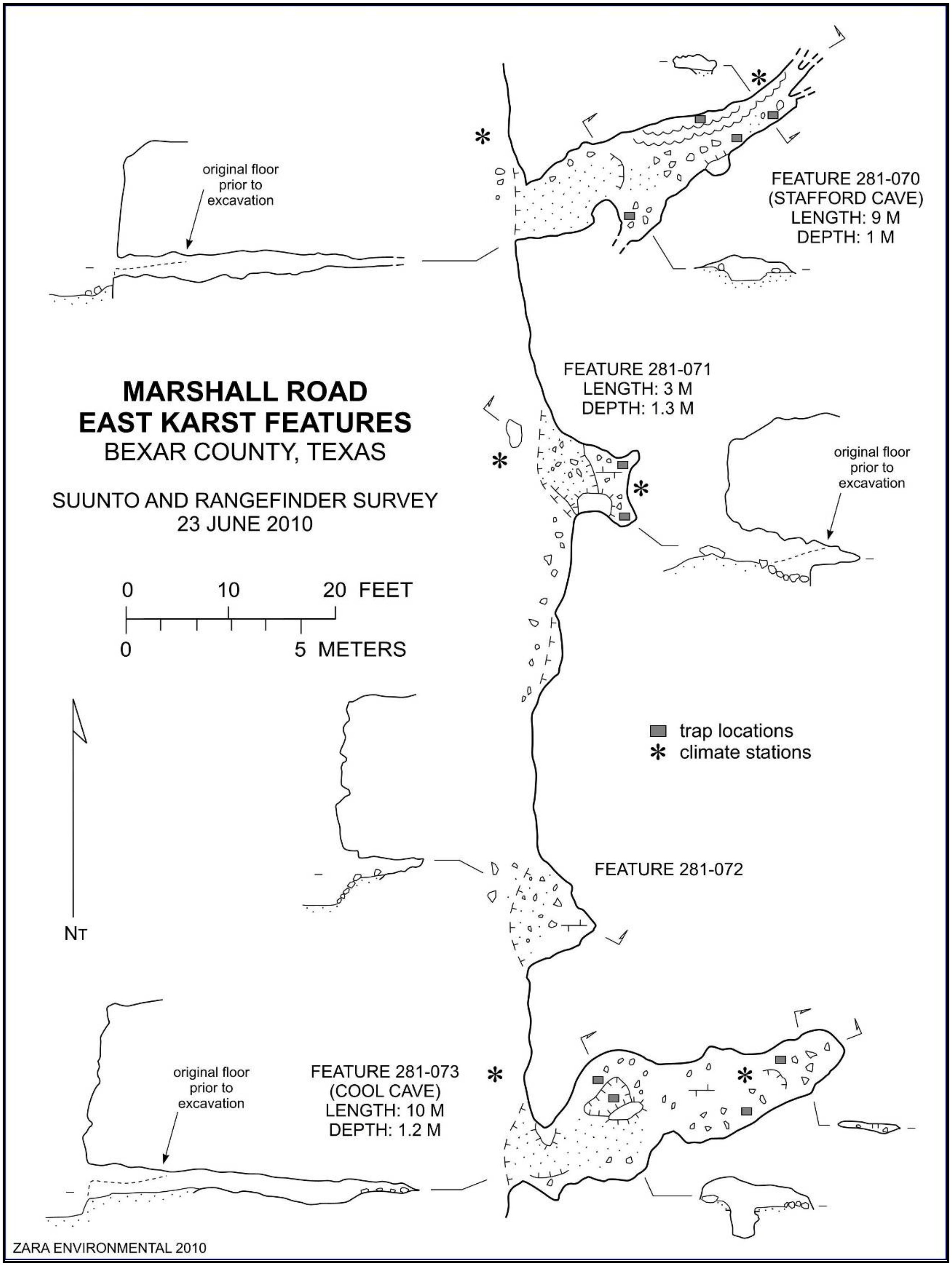
APPENDIX E:
CAVE MAPS

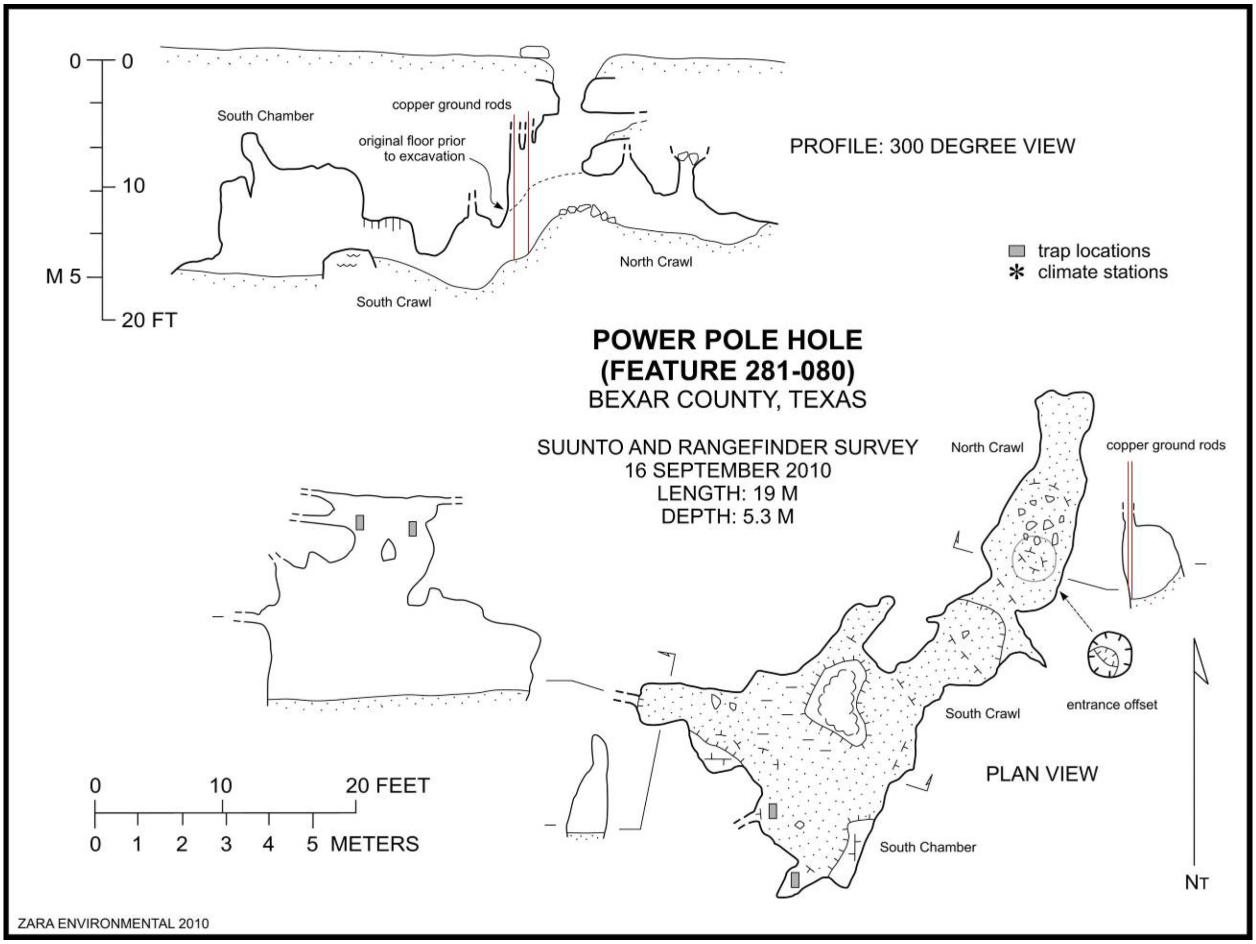

TACO TRUCK TUNNEL
(FEATURE 281-025)
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
17 SEPTEMBER 2010
LENGTH: 5 M
DEPTH: 5 M
trap locations
climate stations
NT
original floor prior to excavation
small karst feature
lower level offset
0 10 20 FEET
0 1 2 3 4 5 METERS
small karst feature
ZARA ENVIRONMENTAL 2010


PAINFUL CRAWL
(281-037)
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
17 SEPTEMBER 2010
LENGTH: 10 M
DEPTH: 0.7 M
trap locations
climate stations
0
10
20 FEET
0
1
2
3
4
5 METERS
ENTRANCE
too low
too low
too low
too low
PLAN
NT
PROFILE: 75 DEGREE VIEW
original floor prior to excavation
0
0
10 FT
M 4
ZARA ENVIRONMENTAL 2010

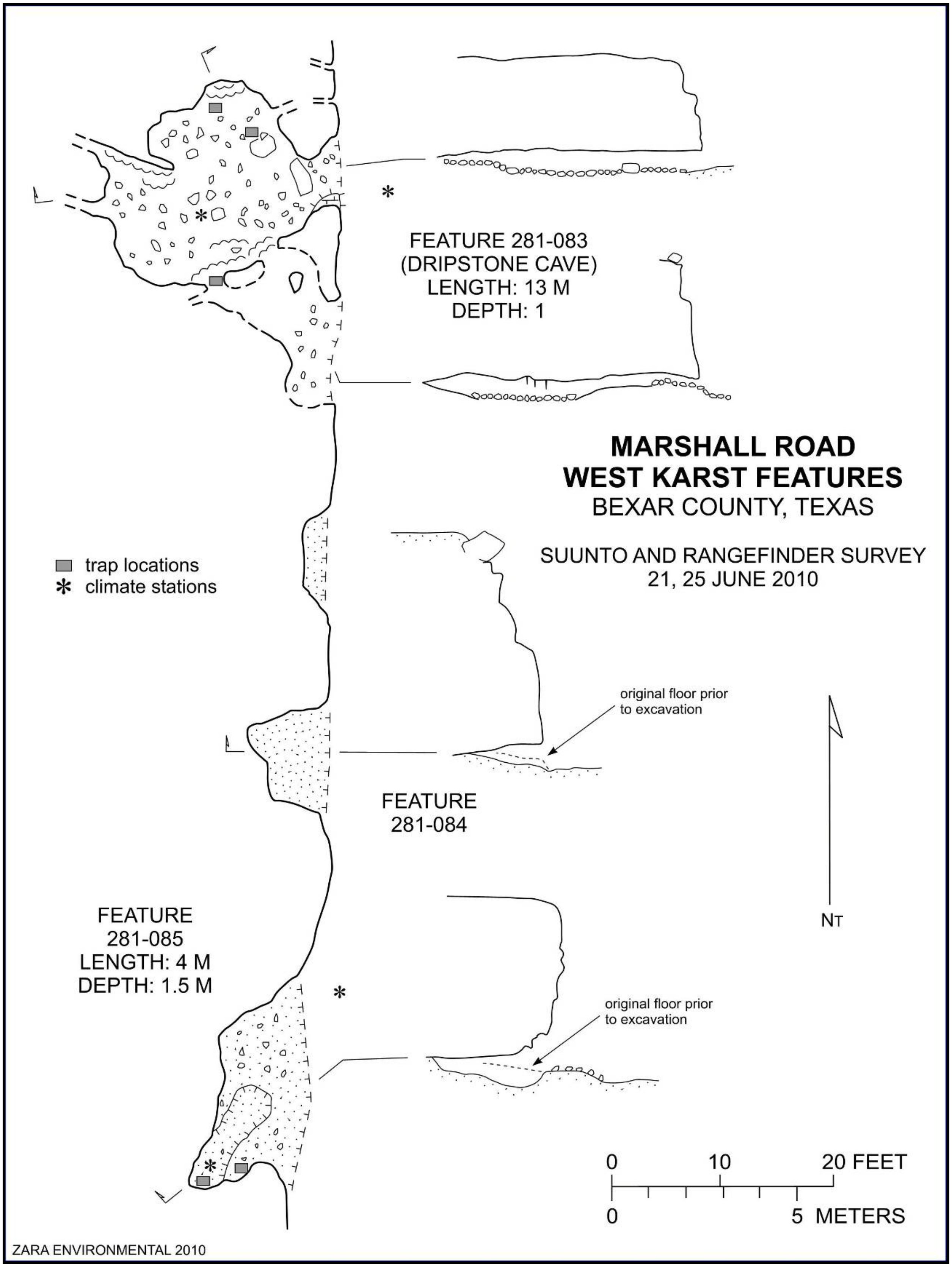

FEATURE 281-045
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
29 SEPTEMBER 2010
LENGTH: 7 M
DEPTH: 0.7 M
NT
trap locations
climate stations
0
10
20 FEET
0
1
2
3
4
5 METERS
ZARA ENVIRONMENTAL 2010

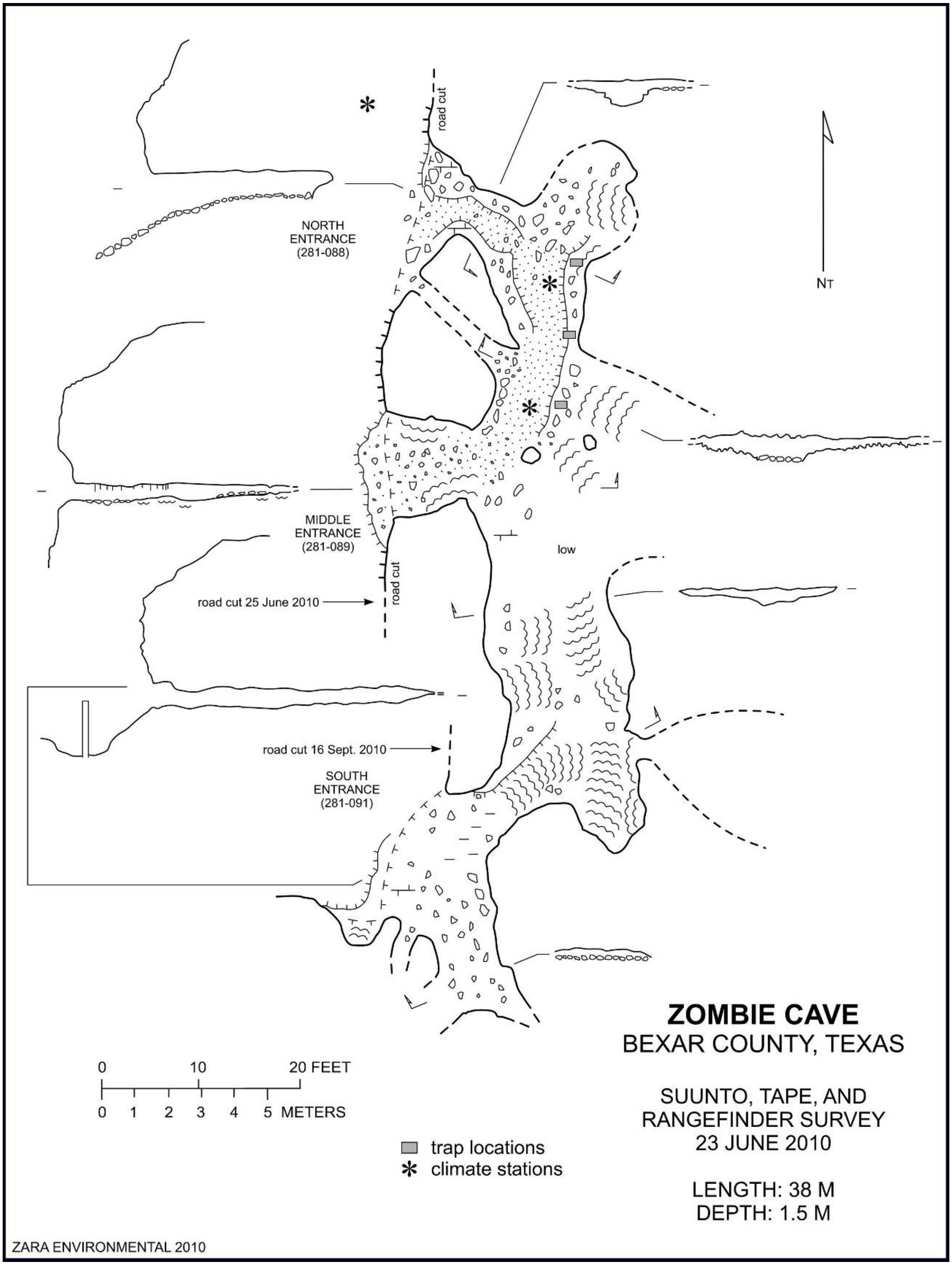

FEATURE 281-063
LENGTH: 7 M
DEPTH: 1.4 M
road cut
original floor
prior to
excavation
ENCINO RIO AREA
KARST FEATURES
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
21 JUNE 2010
road cut
FEATURE 281-062
LENGTH: 5.5 M
DEPTH: 3.4 M
0 10 20 FEET
0 1 2 3 4 5 METERS
trap locations
* climate stations
original floor prior
to excavation
NT
LOWER LEVEL OFFSET
ZARA ENVIRONMENTAL 2010


MARSHALL ROAD
EAST KARST FEATURES
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
23 JUNE 2010
0
10
20 FEET
0
5 METERS
NT
FEATURE 281-070
(STAFFORD CAVE)
LENGTH: 9 M
DEPTH: 1 M
original floor
prior to
excavation
FEATURE 281-071
LENGTH: 3 M
DEPTH: 1.3 M
original floor
prior to
excavation
trap locations
climate stations
FEATURE 281-072
FEATURE 281-073
(COOL CAVE)
LENGTH: 10 M
DEPTH: 1.2 M
original floor
prior to
excavation
ZARA ENVIRONMENTAL 2010

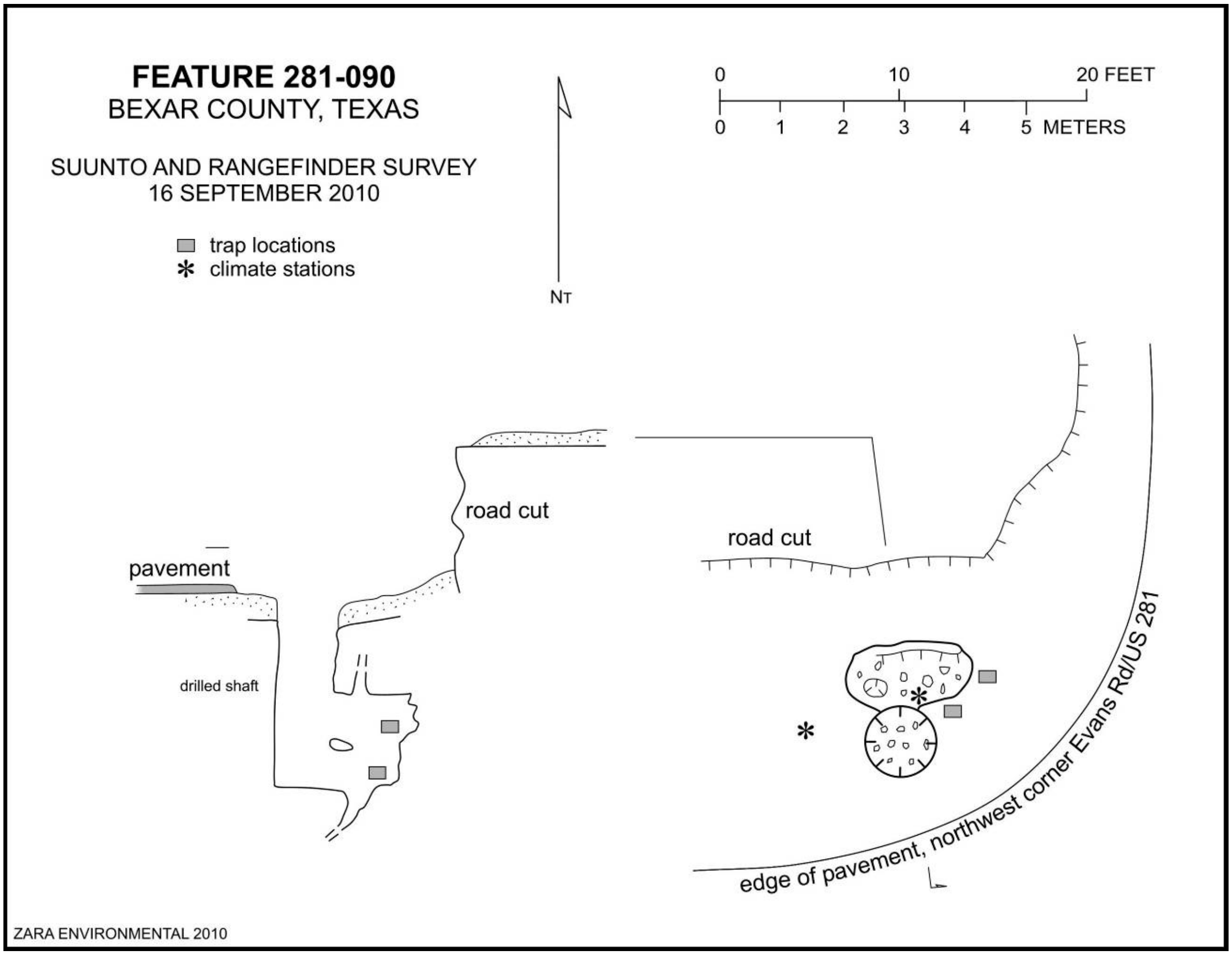


POWER POLE HOLE
(FEATURE 281-080)
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
16 SEPTEMBER 2010
LENGTH: 19 M
DEPTH: 5.3 M
PROFILE: 300 DEGREE VIEW
PLAN VIEW
trap locations
climate stations
South Chamber
copper ground rods
original floor prior to excavation
North Crawl
South Crawl
entrance offset
0
10
M 5
20 FT
0 10 20 FEET
0 1 2 3 4 5 METERS
NT
ZARA ENVIRONMENTAL 2010


FEATURE 281-083
(DRIPSTONE CAVE)
LENGTH: 13 M
DEPTH: 1
MARSHALL ROAD
WEST KARST FEATURES
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
21, 25 JUNE 2010
trap locations
climate stations
original floor prior to excavation
FEATURE 281-084
NT
FEATURE 281-085
LENGTH: 4 M
DEPTH: 1.5 M
original floor prior to excavation
0
10
20 FEET
0
5 METERS
ZARA ENVIRONMENTAL 2010



road cut
NORTH
ENTRANCE
(281-088)
NT
MIDDLE
ENTRANCE
(281-089)
low
road cut
road cut 25 June 2010
road cut 16 Sept. 2010
SOUTH
ENTRANCE
(281-091)
ZOMBIE CAVE
BEXAR COUNTY, TEXAS
0 10 20 FEET
0 1 2 3 4 5 METERS
SUUNTO, TAPE, AND
RANGEFINDER SURVEY
23 JUNE 2010
trap locations
climate stations
LENGTH: 38 M
DEPTH: 1.5 M
ZARA ENVIRONMENTAL 2010



FEATURE 281-090
BEXAR COUNTY, TEXAS
SUUNTO AND RANGEFINDER SURVEY
16 SEPTEMBER 2010
trap locations
climate stations
NT
0
10
20 FEET
0
1
2
3
4
5 METERS
road cut
road cut
pavement
drilled shaft
edge of pavement, northwest corner Evans Rd/US 281
ZARA ENVIRONMENTAL 2010

DRAFT KARST INVERTEBRATE TECHNICAL REPORT FOR US 281 FROM LOOP 1604 TO BORGFELD ROAD, BEXAR COUNTY, TEXAS

APPENDIX F: HISTORIC FEATURES REVIEWED FROM PREVIOUS REPORTS

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
5F1	29.65596	-98.44913	not located, "unable to find - covered"	ROW	AR 1500 2007
5F4	29.65333	-98.44855	not located, "void in loose rock unable to find - covered"	ROW	AR 1500 2007
5F5	29.65159	-98.44900	not located, "CD unable to find - covered" (destroyed)	ROW	AR 1500 2007
5F6	29.65147	-98.44911	not located, "Pot SH unable to find - covered" (destroyed)	ROW	AR 1500 2007
5F7	29.65032	-98.44946	not located, "Pot SC unable to find - covered" (destroyed)	ROW	AR 1500 2007
5F8	29.64180	-98.45343	non-karst closed depression	ROW	AR 1500 2007
5F9	29.64644	-98.45220	not located, "fracture rock now road"	ROW	AR 1500 2007
5F10	29.64949	-98.45117	non-karst closed depression	ROW	AR 1500 2007
5F11	29.65026	-98.45048	not located, "unable to find - cleared" (destroyed)	ROW	AR 1500 2007
7F18	29.65422	-98.44839	not located, under pavement (destroyed)	ROW	AR 1500 2007
B5	29.63548	-98.45691	281-106	ROW	AR 1500 2007
F-1	29.62427	-98.46345	not located, fault	ROW	AR 528 2003
F-01	29.62427	-98.46345	not located, fault	ROW	AR 682 2005
F-2	29.62750	-98.46178	not located, under US 281 pavement (destroyed)	ROW	AR 528 2003
F-02	29.62920	-98.46097	281-061	ROW	AR 682 2005
F3E	29.66682	-98.44925	not located, detention pond	ROW	AR 1500 2007
F-03	29.62946	-98.46080	281-063	ROW	AR 682 2005
F4A	29.65200	-98.45018	281-045	ROW	AR 1500 2007
F4B	29.65198	-98.45027	281-045	ROW	AR 1500 2007
F-04	29.63425	-98.45767	non-karst closed depression from road cut	ROW	AR 682 2005
F5	29.65513	-98.45017	non-karst, animal burrow	ROW	AR 1500 2007
F-5	29.63538	-98.45670	281-106	ROW	AR 528 2003
F-05	29.63522	-98.45670	281-106	ROW	AR 682 2005
F-6	29.64158	-98.45350	not located, fault	ROW	AR 528 2003
F-06	29.64158	-98.45390	not located, fault	ROW	AR 682 2005
F-07	29.64182	-98.45344	non-karst closed depression	ROW	AR 682 2005
F8	29.65020	-98.44981	non-karst closed	ROW	AR 1500 2007

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			depression		
F-08	29.64355	-98.45208	not located, other bedrock feature	ROW	AR 682 2005
F9	29.65442	-98.44859	non-karst closed depression	ROW	AR 1500 2007
F10	29.65422	-98.44858	not located, sinkhole, area has been filled (destroyed)	ROW	AR 1500 2007
F-10	29.65039	-98.45036	non-karst closed depression	ROW	AR 682 2005
F11	29.64065	-98.45398	non-karst closed depression	ROW	AR 1500 2007
F-11	29.65035	-98.44937	non-karst closed depression	ROW	AR 682 2005
F-12	29.65048	-98.44998	281-114	ROW	AR 682 2005
F-13	29.65148	-98.44914	not located, cleared/graded (destroyed)	ROW	AR 682 2005
F-14	29.65162	-98.44899	not located, cleared/graded (destroyed)	ROW	AR 682 2005
F15	29.70753	-98.45031	not located, other (likely burrow)	ROW	AR 1500 2007
F-15	29.65186	-98.45014	281-045	ROW	AR 682 2005
F-16	29.65334	-98.44857	not located, solution cavity	ROW	AR 682 2005
F17	29.68699	-98.45334	281-102	ROW	AR 1500 2007
F-17a	29.65434	-98.44859	281-108	ROW	AR 682 2005
F-17b	29.65434	-98.44859	281-108	ROW	AR 682 2005
F-17c	29.65434	-98.44859	281-108	ROW	AR 682 2005
F-17d	29.65434	-98.44859	281-108	ROW	AR 682 2005
F18	29.62919	-98.46098	281-061	ROW	AR 1500 2007
F-18	29.65419	-98.44838	not located, under pavement (destroyed)	ROW	AR 682 2005
F18A	29.62919	-98.46098	281-061	ROW	AR 1500 2007
F18B	29.62943	-98.46060	281-061	ROW	AR 1500 2007
F19	29.63170	-98.45950	not located, under 281 pavement (destroyed)	ROW	AR 1500 2007
F-19	29.65458	-98.44864	non-karst closed depression	ROW	AR 682 2005
F20	29.63428	-98.45767	not located, under pavement (destroyed)	ROW	AR 1500 2007
F-20	29.65515	-98.45017	non-karst, animal burrow	ROW	AR 682 2005
F21	29.63548	-98.45691	281-106	ROW	AR 1500 2007
F-21	29.65598	-98.44918	not located, solution cavity	ROW	AR 682 2005
F-22	29.66006	-98.45043	281-083	ROW	AR 682 2005

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
F-23	29.65983	-98.45044	281-084	ROW	AR 682 2005
F-24	29.65879	-98.45000	281-075	ROW	AR 682 2005
F-25	29.65990	-98.45051	281-083	ROW	AR 682 2005
F34	29.64020	-98.45500	non-karst, collapse from road cut	ROW	AR 1500 2007
F35	29.63935	-98.45542	not located, developed (destroyed)	ROW	AR 1500 2007
F37	29.63023	-98.46045	not located, solution cavity	ROW	AR 1500 2007
F38	29.62948	-98.46079	281-063	ROW	AR 1500 2007
F39	29.62452	-98.46338	281-060	ROW	AR 1500 2007
F40	29.62242	-98.46454	not located, solution cavity	ROW	AR 1500 2007
F41	29.63428	-98.45768	not located, "artifact of road cut - manmade"	ROW	AR 1500 2007
F42	29.62009	-98.46517	281-104	ROW	AR 1500 2007
F43	29.61355	-98.46768	281-080	ROW	AR 1500 2007
F44	29.62894	-98.46158	not located, closed depression	ROW	AR 1500 2007
F52	29.62922	-98.46098	281-061	ROW	AR 1500 2007
F100	29.66026	-98.44993	281-069-75	ROW	AR 1500 2007
F101	29.65923	-98.45042	281-087	ROW	AR 1500 2007
F102	29.64396	-98.45303	281-082	ROW	AR 1500 2007
F200	29.68204	-98.45362	281-096	ROW	AR 1500 2007
F201	29.64322	-98.45372	non-karst closed depression	ROW	AR 1500 2007
MM-1	29.61868	-98.46551	281-056	ROW	AR 682 2005
MM-2	29.64029	-98.45409	non-karst, man-made trench	ROW	AR 682 2005
MM-2	29.64058	-98.45394	non-karst, trench	ROW	AR 528 2003
MM-3	29.64232	-98.45418	non-karst, sanitary sewer	ROW	AR 682 2005
MM-3	29.64235	-98.45419	non-karst, sanitary sewer	ROW	AR 528 2003
MM-4	29.64672	-98.45185	not located, non-karst per source, sanitary sewer	ROW	AR 682 2005
MM-5	29.64884	-98.45125	not located (removed/destroyed)	ROW	AR 682 2005
MM-7	29.64884	-98.45125	not located (removed/destroyed)	ROW	AR 682 2005
MM-8	29.64884	-98.45125	not located (removed/destroyed)	ROW	AR 682 2005
S-1	29.65880	-98.44997	281-075	ROW	AR 633 2004
S-1	29.63428	-98.45767	non-karst closed depression from road cut	ROW	Pape-Dawson Engineers, Inc. 2009
S-1	29.65443	-98.44859	non-karst closed	ROW	Escarpment

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			depression		Environmental 2005
S-2	29.66006	-98.44987	281-073	ROW	AR 633 2004
S-2	29.63550	-98.45689	281-106	ROW	Pape-Dawson Engineers, Inc. 2009
S-2	29.64767	-98.45129	not located, solution cavity	ROW	Integrated Testing & Engineering Company 2003
S-2	29.65441	-98.44853	non-karst closed depression	ROW	Escarpment Environmental 2005
S-3	29.66025	-98.44993	281-071	ROW	AR 633 2004
S-3	29.66003	-98.44981	281-069 - 73	ROW	Pape-Dawson Engineers, Inc. 2009
S-3	29.64781	-98.45108	not located, non-karst per source, sanitary sewer	ROW	Integrated Testing & Engineering Company 2003
S-3	29.65600	-98.44916	not located, closed depression	ROW	Escarpment Environmental 2005
S-4	29.66001	-98.45049	281-081	ROW	AR 633 2004
S-4	29.65989	-98.45050	281-083, 84 & 85	ROW	Pape-Dawson Engineers, Inc. 2009
S-4	29.62678	-98.46125	281-116	ROW	Intec of San Antonio 2008b
S-4	29.64775	-98.45106	not located, non-karst per source, sanitary sewer	ROW	Integrated Testing & Engineering Company 2003
S-5	29.65985	-98.45049	281-083	ROW	AR 633 2004
S-5	29.65203	-98.45025	281-045	ROW	Pape-Dawson Engineers, Inc. 2009
S-5	29.65000	-98.45096	not located, solution cavity	ROW	Frost GeoSciences, Inc. 2008a
S-6	29.65959	-98.45044	281-086	ROW	AR 633 2004
S-6	29.65203	-98.45025	281-045	ROW	Pape-Dawson Engineers, Inc. 2009
S-6	29.65067	-98.45073	not located, solution cavity	ROW	Frost GeoSciences, Inc. 2008a
S-6	29.62678	-98.46125	281-116	ROW	Intec of San Antonio 2007
S-6	29.64747	-98.45203	not located, solution cavity	ROW	Integrated Testing & Engineering Company 2003
S-7	29.65924	-98.45046	281-087	ROW	AR 633 2004

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
S-7	29.65203	-98.45025	non-karst closed depression, stream scour	ROW	Pape-Dawson Engineers, Inc. 2009
S-8	29.64689	-98.45211	not located, non-karst per source, sanitary sewer	ROW	Pape-Dawson Engineers, Inc. 2009
S-8	29.64728	-98.45204	not located, solution cavity	ROW	Integrated Testing & Engineering Company 2003
S-9	29.64608	-98.45206	not located, solution fracture	ROW	Pape-Dawson Engineers, Inc. 2009
S-9	29.64728	-98.45204	not located, solution cavity	ROW	Integrated Testing & Engineering Company 2003
S-10	29.63450	-98.45811	281-081	ROW	Pape-Dawson Engineers, Inc. 2009
S-10	29.64667	-98.45175	not located, non-karst per source, sanitary sewer	ROW	Integrated Testing & Engineering Company 2003
S-11	29.62931	-98.46092	281-066	ROW	Pape-Dawson Engineers, Inc. 2009
S-11	29.64675	-98.45197	not located, non-karst per source, sanitary sewer	ROW	Integrated Testing & Engineering Company 2003
S-12	29.63967	-98.45522	not located, fault	ROW	Pape-Dawson Engineers, Inc. 2009
S-12	29.64675	-98.45199	not located, non-karst per source, culvert	ROW	Integrated Testing & Engineering Company 2003
S-13	29.63506	-98.45742	not located, fault	ROW	Pape-Dawson Engineers, Inc. 2009
S-13	29.64672	-98.45197	not located, non-karst per source, culvert	ROW	Integrated Testing & Engineering Company 2003
S-14	29.64053	-98.45403	non-karst closed depression	ROW	Pape-Dawson Engineers, Inc. 2009
S-14	29.64642	-98.45174	not located, non-karst per source, sanitary sewer lift station	ROW	Integrated Testing & Engineering Company 2003
S-15	29.64089	-98.45403	non-karst closed depression	ROW	Pape-Dawson Engineers, Inc. 2009
S-16	29.64247	-98.45322	281-077	ROW	Pape-Dawson Engineers, Inc.

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
					2009
S-16	29.65036	-98.44945	non-karst closed depression	ROW	Escarpment Environmental 2005
S-17	29.65422	-98.44842	non-karst closed depression	ROW	Pape-Dawson Engineers, Inc. 2009
S-18	29.62936	-98.46088	281-062	ROW	Pape-Dawson Engineers, Inc. 2009
S-19	29.64433	-98.45253	281-115	ROW	Pape-Dawson Engineers, Inc. 2009
S-20	29.65318	-98.44863	non-karst closed depression	ROW	Escarpment Environmental 2005
S-21	29.64986	-98.45022	not located, fault	ROW	Pape-Dawson Engineers, Inc. 2009
S-21	29.65334	-98.44852	not located, solution fracture	ROW	Escarpment Environmental 2005
S-22A	29.65417	-98.44835	not located, under pavement (destroyed)	ROW	Escarpment Environmental 2005
S-22B	29.65417	-98.44835	not located, under pavement (destroyed)	ROW	Escarpment Environmental 2005
S-22C	29.65417	-98.44835	not located, under pavement (destroyed)	ROW	Escarpment Environmental 2005
S-23A	29.65424	-98.44853	not located, area has been filled	ROW	Escarpment Environmental 2005
S-23B	29.65424	-98.44853	not located, area has been filled	ROW	Escarpment Environmental 2005
S-23C	29.65424	-98.44853	not located, area has been filled	ROW	Escarpment Environmental 2005
S-25	29.65437	-98.44866	non-karst closed depression	ROW	Escarpment Environmental 2005
S-26	29.65434	-98.44872	non-karst closed depression	ROW	Escarpment Environmental 2005
Tiny Town Sink			Reported destroyed in 1973	ROW	TSS 2010
C-Section Cave			appears to have been cleared, may be	500 ft buffer	TSS 2010

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			removed (destroyed)		
F1	29.63878	-98.45456	no access - not located, developed (destroyed)	500 ft buffer	AR 1500 2007
F2	29.70027	-98.45099	281-099	500 ft buffer	AR 1500 2007
F-2	29.67849	-98.45388	no access - not located, solution cavity	500 ft buffer	AR 699 2005
F3	29.70147	-98.45077	281-004	500 ft buffer	AR 1500 2007
F-3	29.67859	-98.45388	no access - not located, sinkhole	500 ft buffer	AR 699 2005
F6	29.64953	-98.45160	281-043	500 ft buffer	AR 1500 2007
F7	29.64940	-98.45151	non-karst closed depression	500 ft buffer	AR 1500 2007
F7E	29.67537	-98.45145	no access - not located, other bedrock feature	500 ft buffer	AR 1500 2007
F8E	29.68303	-98.45285	281-033	500 ft buffer	AR 1500 2007
F11E C	29.70470	-98.44930	not located, fractured bedrock in creek	500 ft buffer	AR 1500 2007
F12E	29.69557	-98.45118	281-100	500 ft buffer	AR 1500 2007
F13E B	29.70873	-98.44854	not located, exposed bedrock	500 ft buffer	AR 1500 2007
F16	29.68789	-98.45325	no access - not located, sinkhole	500 ft buffer	AR 1500 2007
F18	29.69187	-98.45204	no access - not located, closed depression	500 ft buffer	AR 1500 2007
F19	29.70195	-98.45223	no access - not located, bulldozed/filled/trash	500 ft buffer	AR 1500 2007
F20	29.69292	-98.45326	281-014	500 ft buffer	AR 1500 2007
F20W	29.70561	-98.45107	281-098	500 ft buffer	AR 1500 2007
F21	29.68630	-98.45357	no access - not located, sinkhole	500 ft buffer	AR 1500 2007
F21W	29.70235	-98.45159	no access - not located, animal burrow	500 ft buffer	AR 1500 2007
F22	29.68335	-98.45438	no access - not located, bulldozer scar	500 ft buffer	AR 1500 2007
F223	29.62684	-98.46297	no access - not located, unknown	500 ft buffer	AR 1500 2007

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
F-23 cave	29.67847	-98.45393	no access - not located, cave	500 ft buffer	TSS 2010
F24	29.67921	-98.45397	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
F25	29.67589	-98.45349	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
F26	29.67581	-98.45350	no access - not located, solution enlarged fracture	500 ft buffer	AR 1500 2007
F28	29.66635	-98.44832	no access - not located, sinkhole/closed depression	500 ft buffer	AR 1500 2007
F29	29.65066	-98.45077	not located, solution fracture	500 ft buffer	AR 1500 2007
F2E	29.66683	-98.44909	no access - not located, septic tank	500 ft buffer	AR 1500 2007
F30	29.66536	-98.45040	no access - not located, closed depression/solution cavity	500 ft buffer	AR 1500 2007
F31	29.64772	-98.45231	non-karst, animal burrow	500 ft buffer	AR 1500 2007
F32	29.64769	-98.45276	non-karst closed depression	500 ft buffer	AR 1500 2007
F33	29.64344	-98.45394	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
F36	29.64043	-98.45603	not located, developed (destroyed)	500 ft buffer	AR 1500 2007
F45	29.62965	-98.46148	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
F46	29.62691	-98.46290	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
F47	29.62684	-98.46297	no access - not located, cave	500 ft buffer	AR 1500 2007
F49	29.65259	-98.45114	not located, solution cavity	500 ft buffer	AR 1500 2007
F51	29.64852	-98.45205	no access - not located, solution cavity	500 ft buffer	AR 1500 2007
LineAStation11+30	29.64678	-98.45004	not located, filled (destroyed) per source	500 ft buffer	Frost GeoSciences, Inc. 2008d
LineAStation11+	29.64678	-98.45021	not located, filled (destroyed) per	500 ft buffer	Frost GeoSciences, Inc. 2008d

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
60			source		
S1-11	29.63934	-98.45375	not located, graded (destroyed)	500 ft buffer	Pape-Dawson Engineers, Inc. 2004
S1-84	29.63922	-98.45413	not located, graded (destroyed)	500 ft buffer	Pape-Dawson Engineers, Inc. 2004
S-1	29.63653	-98.45383	no access - not located, non-karst per source, culvert	500 ft buffer	DNA Geosciences, Inc. 2005
S-1	29.62997	-98.45786	no access - not located, non-karst per source	500 ft buffer	Intec of San Antonio 2008a
S-1	29.64058	-98.45369	non-karst, sanitary sewer	500 ft buffer	Pape-Dawson Engineers, Inc. 2008
S-1	29.67441	-98.45411	no access - not located, fractured bedrock	500 ft buffer	Frost GeoSciences, Inc. 2008c
S-1	29.61414	-98.46772	non-karst, sanitary sewer	500 ft buffer	Pape-Dawson Engineers, Inc. 2007a
S-1	29.63819	-98.45737	no access - not located, closed depression	500 ft buffer	Pape-Dawson Engineers, Inc. 2007b
S-1	29.63819	-98.45737	not located, non-karst per source, animal burrow	500 ft buffer	Pape-Dawson Engineers, Inc. 2007c
S-1	29.62736	-98.46047	no access - not located, fractured bedrock	500 ft buffer	Intec of San Antonio 2008b
S-1	29.62628	-98.46131	no access - not located, solution cavity	500 ft buffer	Intec of San Antonio 2007
S-1	29.64814	-98.45202	not located, solution cavity	500 ft buffer	Integrated Testing & Engineering Company 2003
S-1	29.66109	-98.44898	no access - not located, non-karst closed depression per source	500 ft buffer	Gulf Coast Compliance, Inc. 2007
S-1	29.64800	-98.44856	no access - not located, non-karst per source, man-made excavation	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-1	29.63619	-98.45347	no access - not located, closed depression	500 ft buffer	Neathery Environmental 2007
S-1a	29.62628	-98.46131	no access - not located, non-karst per	500 ft buffer	Intec of San Antonio 2007

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			source		
S-2	29.63000	-98.45783	no access - not located, non-karst per source	500 ft buffer	Intec of San Antonio 2008a
S-2	29.67281	-98.45236	no access - not located, solution cavity	500 ft buffer	Frost GeoSciences, Inc. 2008c
S-2	29.65025	-98.45213	non-karst, surficial vuggy rock	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-2	29.62772	-98.45983	no access - not located, non-karst per source	500 ft buffer	Intec of San Antonio 2008b
S-2	29.62717	-98.46072	no access - not located, fractured bedrock	500 ft buffer	Intec of San Antonio 2007
S-2	29.66139	-98.44888	no access - not located, non-karst closed depression per source	500 ft buffer	Gulf Coast Compliance, Inc. 2007
S-2	29.64806	-98.44936	no access - not located, fractured bedrock	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-2	29.64720	-98.44929	no access - not located, fault	500 ft buffer	Frost GeoSciences, Inc. 2007
S-2	29.62258	-98.46270	no access - area is disturbed/developed (destroyed)	500 ft buffer	Duduit, T. J. 2005
S-3	29.68474	-98.45486	septic tank	500 ft buffer	Frost GeoSciences, Inc. 2009
S-3	29.67452	-98.45306	no access - not located, solution cavity	500 ft buffer	Frost GeoSciences, Inc. 2008c
S-3	29.61411	-98.47033	no access - not located, zone of non-karst closed depressions	500 ft buffer	Pape-Dawson Engineers, Inc. 2007a
S-3	29.65025	-98.45210	non-karst, surficial vuggy rock	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-3	29.62736	-98.46047	no access - not located, fractured bedrock	500 ft buffer	Intec of San Antonio 2007
S-3	29.66210	-98.44884	no access - not located, non-karst closed depression per source	500 ft buffer	Gulf Coast Compliance, Inc. 2007
S-3	29.64781	-98.44931	no access - not located, fractured bedrock	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-3	29.62255	-98.46272	no access - area is disturbed/developed	500 ft buffer	Duduit, T. J. 2005

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			(destroyed)		
S-4	29.68469	-98.45483	collapsed cellar	500 ft buffer	Frost GeoSciences, Inc. 2009
S-4	29.65025	-98.45213	non-karst, surficial vuggy rock	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-4	29.62772	-98.45983	no access - not located, non-karst per source	500 ft buffer	Intec of San Antonio 2007
S-4	29.66201	-98.44881	no access - not located, non-karst closed depression per source	500 ft buffer	Gulf Coast Compliance, Inc. 2007
S-4	29.64775	-98.44911	no access - not located	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-4	29.65669	-98.44738	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-5	29.63919	-98.45737	no access - not located, fault	500 ft buffer	Pape-Dawson Engineers, Inc. 2007b
S-5	29.63919	-98.45737	no access - not located, fault	500 ft buffer	Pape-Dawson Engineers, Inc. 2007c
S-5	29.62572	-98.46133	no access - not located, non-karst per source	500 ft buffer	Intec of San Antonio 2007
S-5	29.64747	-98.45240	281-109	500 ft buffer	Integrated Testing & Engineering Company 2003
S-5	29.64744	-98.44925	no access - not located	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-5	29.62252	-98.46278	no access - area is disturbed/developed (destroyed)	500 ft buffer	Duduit, T. J. 2005
S-6	29.66326	-98.44859	not located, cleared/graded (destroyed)	500 ft buffer	Pape-Dawson Engineers, Inc. 2002
S-6	29.62232	-98.46315	no access - area is disturbed/developed (destroyed)	500 ft buffer	Duduit, T. J. 2005
S-7	29.66336	-98.44870	281-037	500 ft buffer	Pape-Dawson Engineers, Inc. 2002
S-7	29.64975	-98.45132	281-097	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-7	29.64725	-98.45221	not located, solution cavity	500 ft buffer	Integrated Testing & Engineering Company 2003
S-7	29.64697	-98.44886	no access - not located, fractured	500 ft buffer	Frost GeoSciences, Inc. 2005a

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			bedrock		
S-7	29.64720	-98.44916	no access - not located, fractured bedrock	500 ft buffer	Frost GeoSciences, Inc. 2005b
S-7	29.62222	-98.46338	no access - area is disturbed/developed (destroyed)	500 ft buffer	Duduit, T. J. 2005
S-7	29.65443	-98.44761	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-8	29.66314	-98.44956	not located, under pavement (destroyed)	500 ft buffer	Pape-Dawson Engineers, Inc. 2002
S-8	29.66077	-98.45050	not located, well	500 ft buffer	Frost GeoSciences, Inc. 2008b
S-8	29.64309	-98.45537	no access - not located, developed (destroyed)	500 ft buffer	Pape-Dawson Engineers, Inc. 2007b
S-8	29.64967	-98.45171	non-karst, surficial vuggy rock	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-8	29.64711	-98.44944	no access - not located, fractured bedrock	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-8	29.62223	-98.46338	no access - area is disturbed/developed (destroyed)	500 ft buffer	Duduit, T. J. 2005
S-8	29.65555	-98.44866	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-9	29.66197	-98.45061	not located, man-made feature per source	500 ft buffer	Frost GeoSciences, Inc. 2008b
S-9	29.62544	-98.45800	no access - not located, other bedrock feature	500 ft buffer	Intec of San Antonio 2008a
S-9	29.64953	-98.45157	281-043	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-9	29.65612	-98.44879	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-10	29.64939	-98.45143	non-karst closed depression	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-10	29.64987	-98.44923	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-11	29.62572	-98.46133	no access - not located, other bedrock feature	500 ft buffer	Intec of San Antonio 2008a
S-11	29.64959	-98.45174	non-karst, animal burrow	500 ft buffer	Frost GeoSciences, Inc. 2008a

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
S-11	29.64973	-98.44936	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-11a	29.62572	-98.46133	no access - not located, closed depression	500 ft buffer	Intec of San Antonio 2008a
S-12	29.62628	-98.46131	no access - not located, solution cavity	500 ft buffer	Intec of San Antonio 2008a
S-12	29.64678	-98.44928	281-115	500 ft buffer	Frost GeoSciences, Inc. 2005a
S-12	29.64720	-98.44929	no access - not located, fault	500 ft buffer	Frost GeoSciences, Inc. 2005b
S-12	29.64929	-98.44867	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-13	29.64937	-98.44853	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-14	29.65117	-98.45068	not located, solution cavity	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-14	29.64952	-98.44863	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-15	29.65117	-98.45068	non-karst, surficial vuggy rock	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-15	29.65039	-98.44905	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-16	29.65284	-98.45032	not located, solution cavity	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-18	29.65157	-98.44806	not located, under pavement (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-19	29.65252	-98.44839	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-24	29.65452	-98.44815	no access - not located, developed (destroyed)	500 ft buffer	Escarpment Environmental 2005
S-30	29.67381	-98.45196	no access - not located, fractured bedrock	500 ft buffer	Frost Environmental 2003
S-31	29.65628	-98.45124	281-103	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-31	29.67372	-98.45254	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-32	29.67147	-98.45216	no access - not located, solution	500 ft buffer	Frost Environmental

Historic ID	Latitude (NAD83)	Longitude (NAD 83)	Status and Description	Location	Source
			cavity		2003
S-33	29.65645	-98.45102	281-046	500 ft buffer	Frost GeoSciences, Inc. 2008a
S-33	29.67089	-98.45196	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-34	29.67089	-98.45149	no access - not located, cave	500 ft buffer	Frost Environmental 2003
S-35	29.67186	-98.45129	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-36	29.67300	-98.45378	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-37	29.67314	-98.45378	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-42	29.67450	-98.45433	no access - not located, surficial vuggy outcrop	500 ft buffer	Frost Environmental 2003
S-43	29.67425	-98.45381	no access - not located, fractured bedrock	500 ft buffer	Frost Environmental 2003
S-44	29.67147	-98.45216	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-45	29.67394	-98.45306	no access - not located, solution cavity	500 ft buffer	Frost Environmental 2003
S-46	29.67372	-98.45417	no access - not located, fractured bedrock	500 ft buffer	Frost Environmental 2003
S-100	29.63819	-98.45764	not located, non-karst per source, sanitary sewer	500 ft buffer	Pape-Dawson Engineers, Inc. 2007c
SPRE	29.70876	-98.44871	not located, spring	500 ft buffer	AR 1500 2007
Voight Cave No. 1			appears to be under pavement (destroyed)	500 ft buffer	TSS 2010

Texas Speleological Survey Records

The TSS database shows a total of three caves occurring within the study area that were not located. These caves are either destroyed or located on property where access was not granted. Below is a list of the caves and any other information included in the database.

Literature Cited Appendix F

Administrative Record (AR) Document 528. 2003. Geologic Assessment for US 281 from Sonterra Blvd. (Station 346+75) to 0.56 Mile North of Evans Road (Station 377+15), San Antonio, Texas. Turner, Collie & Braden, Inc. Douglas Zarker, P.G. 8 January.

AR Document 633. 2004. Karst Feature Description Forms, US 281. 1 July.

AR Document 682. 2005. Geologic Assessment in the Water Pollution Abatement Plan for US 281 from Loop 1604 to Marshall Road, San Antonio, Bexar County, Texas, CSJ: 0253-04-114, Turner, Collie & Braden, Inc. Douglas Zarker, P.G. 1 March.

AR Document 699. 2005. US 281 from Evans Road to FM 306; Karst Habitat Assessment. ACI Consulting. 1 April.

AR Document 1500. 2005. US 281 from Evans Road to FM 306; Karst Habitat Assessment. ACI Consulting. April.

AR Document 1500. 2007, Environmental Document, US 281 from Loop 1604 to Borgfeld Road, CSJs: 0253-04-089, 0253-04-093, 0253-04-112, 0253-04-114, HNTB Corporation. May 2007.

DNA GeoSciences, Inc. 2005. Geologic Assessment for Encino Commons Driveway Improvements. Jeffery S. Neathery, P.G. 11 July. Texas Commission on Environmental Quality Document No. 242700.

Duduit, T. J., P.G. 2005. Geologic Assessment for Redland Road Commercial Subdivision. 2 June. Texas Commission on Environmental Quality Document No. 236600.

Escarpment Environmental. 2005. Geologic Assessment for Village at Stone Oaks. Kristen M. White, P.G. 19 May. Texas Commission on Environmental Quality Document No. 234601.

Frost Environmental. 2003. Geologic Assessment for Tuscany Heights 1 and 2. Steve Frost, P.G. 6 November. Texas Commission on Environmental Quality Document No. 216401.

Frost GeoSciences, Inc. 2009. Geologic Assessment for Cross Bridge Community Church. Steve Frost, P.G. 1 May. Texas Commission on Environmental Quality Document No. 287001.

Frost GeoSciences, Inc. 2008a. Geologic Assessment for Tacara 59.25 Acres. Steve Frost, P.G. 24 March. Texas Commission on Environmental Quality Document No. 283500.

Frost GeoSciences, Inc. 2008b. Geologic Assessment for Mission Park Tract. Thomas Hernandez, Jr., P.G. 11 February. Texas Commission on Environmental Quality Document No. 281200.

Frost GeoSciences, Inc. 2008c. Geologic Assessment for the Shops at Wilderness Oaks, +/- 29 Acres. Steve Frost, P.G. 15 March. Texas Commission on Environmental Quality Document No. 283000.

Frost GeoSciences, Inc. 2008d. Geologic Assessment for JMS Family, LTD. Steve Frost, P.G. 19 June. Texas Commission on Environmental Quality Document No. 238506.

Frost GeoSciences, Inc. 2007. Geologic Assessment for the Stoltz Commercial. Thomas Hernandez, Jr., P.G. 27 November. Texas Commission on Environmental Quality Document No. 238503.

Frost GeoSciences, Inc. 2005a. Geologic Assessment for the Stoltz Commercial Tract; 7.47 Acres. Chris Wickman, P.G. 27 June. Texas Commission on Environmental Quality Document No. 238500.

Frost GeoSciences, Inc. 2005b. Geologic Assessment for the Stoltz Commercial Tract; +/- 1000 Linear Feet. Steve Frost, P.G.30 June. Texas Commission on Environmental Quality Document No. 238501.

Gulf Coast Compliance, Inc. 2007. Geologic Assessment for Oldcastle APG Texas, Inc. dba Custom Stone Supply. D. Bryan Pairsh, P.G. 4 June. Texas Commission on Environmental Quality Document No. 119707.

Intec of San Antonio. 2007. Geologic Assessment for Vista Point. Jeffery S. Neathery, P.G. 28 September. Texas Commission on Environmental Quality Document No. 276302.

Intec of San Antonio. 2008a. Geologic Assessment for Northside Church of Christ Mass Grading. Jeffery S. Neathery, P.G. 11 February. Texas Commission on Environmental Quality Document No. 277600.

Intec of San Antonio. 2008b. Geologic Assessment for Vista Point Professional Center. Jeffery S. Neathery, P.G. 15 October. Texas Commission on Environmental Quality Document No. 276301.

Integrated Testing & Engineering Company. 2003. Geologic Assessment for the Cactus Bluff Commercial, Unit 2. Daniel Alvarado, P.G. 13 March. Texas Commission on Environmental Quality Document No. 200200.

Neathery Environmental 2007. Geologic Assessment for Pinnacle at Encino Commons. Jeffery S. Neathery, P.G. 7 August. Texas Commission on Environmental Quality Document No. 216501.

Pape-Dawson Engineers, Inc. 2009. Geologic Assessment for US 281 Superstreet. Philip Pearce, P.G. 22 May.

Pape-Dawson Engineers, Inc. 2008. Geologic Assessment for the Plaza at Encino Commons. Philip Pearce, P.G. 8 January. Texas Commission on Environmental Quality Document No. 278200.

Pape-Dawson Engineers, Inc. 2007a. Geologic Assessment for CIRI Tract, 22.75 +/- Acres. Philip Pearce, P.G. 11 May. Texas Commission on Environmental Quality Document No. 278400.

Pape-Dawson Engineers, Inc. 2007b. Geologic Assessment for Stone Ridge Market Retail Center. Philip Pearce, P.G. 8 June. Texas Commission on Environmental Quality Document No. 267200.

Pape-Dawson Engineers, Inc. 2007c. Geologic Assessment for Stone Ridge Market Retail Center. Philip Pearce, P.G. 11 July. Texas Commission on Environmental Quality Document No. 267201.

Pape-Dawson Engineers, Inc. 2004. Geologic Assessment for Encino Commons Mass Grading and Driveway. Philip Pearce, P.G. 23 March. Texas Commission on Environmental Quality Document No. 216500.

Pape-Dawson Engineers, Inc. 2002. Geologic Assessment for Ancira Enterprises-U.S. 281. Philip Pearce, P.G. 10 April. Texas Commission on Environmental Quality Document No. 188600.

Texas Speleological Survey. 2010. Data request for caves in Bexar County.